Instruments

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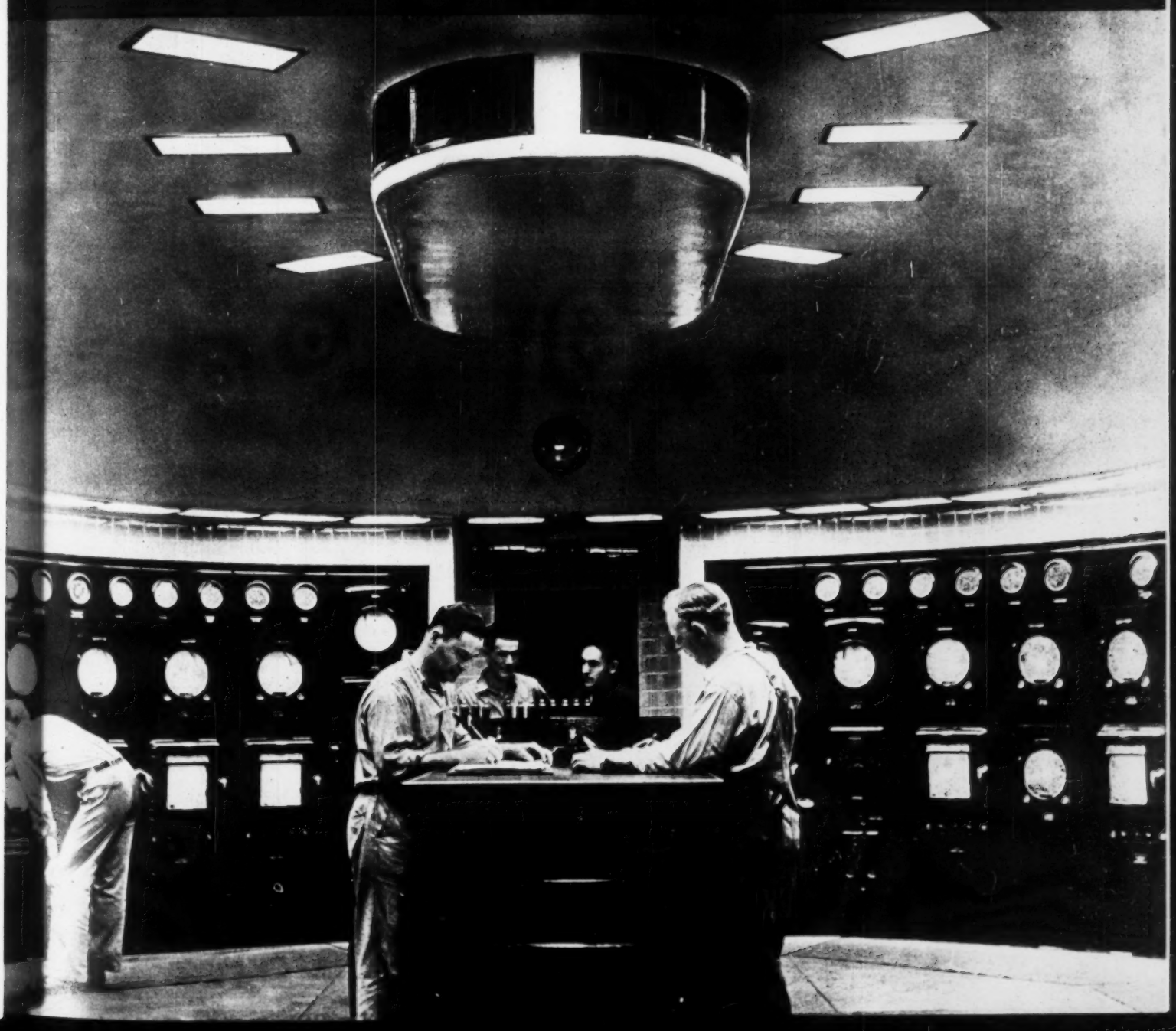
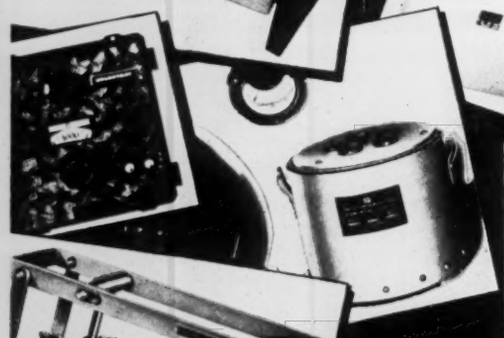
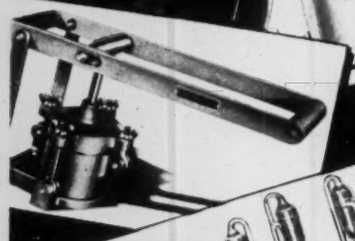
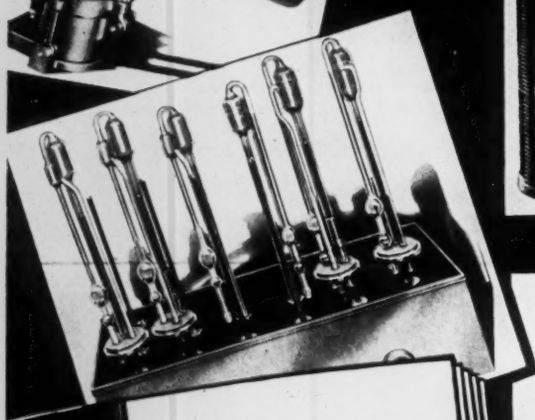
No. 3

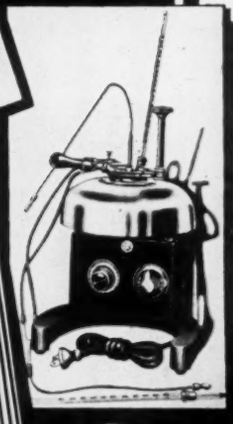


TAG Instruments for Testing Materials









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. . . TAG CELECTRAY Pyrometers control laboratory furnaces to 0.1° . . . 0.01° . . . or one microvolt because they alone utilize high speed photoelectric action, employing a photoelectric tube, a mirror galvanometer and a beam of light.

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Your particular attention is directed to the illustrations at the right of TAG's Yellow-Back WIDE Bore A.S.T.M. Thermometers and TAG's A.P.I. Certified Hydrometers. These improved instruments are accepted standards for temperature and gravity measurement throughout the oil industry.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Instrumentation Receives the Accolade

IT has been a pleasure to report, on this page or elsewhere in *Instruments*, all evidences of active interest in Instrumentation officially displayed by scientific and engineering organizations. Now, for the first time, but heartily, we hail the American Association for the Advancement of Science which has called for next August what will be the longest and most thoroughgoing conference on Instrumentation ever held. The following abstract of the official notice speaks for itself:

A. A. A. S.—Gibson Island Conferences

NEIL E. GORDON, Director
JOHN C. KRANTZ, JR., Assistant Director

This is the fifth summer that special research conferences have been held at Gibson Island under auspices of the American Association for the Advancement of Science. During this five-year period they have grown from two weeks in the summer of 1938 to ten weeks in 1942. Because of this growth the association has purchased a property, and the conferences are now placed on a permanent basis.

These Gibson Island conferences owe their excellence and popularity to careful planning of the programs by experts, choice of the invited contributors, freedom with which contributors make excursions along and sometimes beyond the frontiers of the known, opportunities for abundant discussion, limitation of participants to 60, and delightful surroundings. . . . Conferences for the summer of 1942:

A. Frontiers in Petroleum Chemistry. C. R. Wagner, chairman; Robert E. Burk, Vice Chairman. June 15-19.
B. Catalysis. E. C. Williams, Chairman; Hugh S. Taylor, Vice Chairman. June 22-26.
C. Relation of Structure to Physiological Action. D. L. Tabern, Chairman; W. H. Hartung, Vice Chairman. June 29-July 3.
D. Organic High Molecular Weight Compounds. S. S. Kistler, Chairman; H. Mark, Vice Chairman. June 6-10.
E. Structure and Chemistry of Textile Fibers. Milton Harris, Chairman; H. Spurlin, Vice Chairman. July 13-17.
F. Vitamins. Walter C. Russell, Chairman; R. Adams Dutcher, Vice Chairman. July 20-24.
G. X-Ray and Electron Diffraction. B. E. Warren, Chairman; A. L. Patterson, Vice Chairman. July 27-31.
H. Corrosion. R. M. Burns, Chairman; R. B. Mears, Vice Chairman. August 3-7.
I. Chemical Growth Promoters. E. S. Cook, Chairman; Dean Burk, Vice Chairman. August 17-21.

J. Instrumentation. John J. Grebe, Chairman; Richard Rimbach, Vice Chairman.

August 24. M. F. Béhar: General Discussion, Terminology, Symbols, Dimensional Analysis. H. S. Winniki and J. J. Grebe: Designing Process Equipment to Obtain Self-Regulation, Advance Notice Devices, Time Control, and Ratio Control.

August 25. Bradford Noyes, M. J. Zucrow, and W. G. Brombacher: Requirements of Measuring and Detecting Elements, Sensitivity, Instrument Lags, and Location. Ralph H. Müller: Detecting and Measuring Elements for Chemical Conditions or Composition, Sampling, and Electrode Design.

August 26. Charles S. Draper and K. J. DeJuhasz: Indicating and Recording Devices—Their Sensitivity, Lags, Types and Methods; Metering, Weighing, Integrating. C. O. Fairchild and R. W. Gilbert: Electronic Devices as a Class of Measuring and Control Equipment.

August 27. C. E. Mason: Stability of Processes and Instruments Using Floating and Proportional Position Responses. J. C. Peters: Application of Second Derivative and Special Function Response.

August 28. H. Ziebolz and R. D. Webb: Characteristics of Primary Relays, Power Units, Servo Mechanisms, Control Valves, Pipes, and Pumps. Gordon Brown: Mathematical Analysis; Methods of Obtaining Highest Speeds and Accuracy.

Gibson Island is situated in Chesapeake Bay about 20 miles south of Baltimore. It is approximately 1,000 acres in area and is connected with the mainland by a causeway. Admission to this privately controlled island is by card only from the Gibson Island Club sent by the director at the time of registration. The island offers opportunity for golf, tennis, salt and fresh water bathing, fishing, and sailing.

The conference property provides accommodations for about 50 men in addition to a conference room. . . .

Substantial gifts by industrial companies whose laboratories have been represented at the Gibson Island conferences have enabled the association to purchase the property. Each contributing company has the right to have a representative at each conference. This is a substantial right because there have been many more applicants for admission to the conferences than can be accommodated unless the limit of 60 that has been set is exceeded. The participants have felt that to enlarge the conferences would take from them something of the informality and intimate contacts that make them most valuable. Companies that have made the purchase of this property possible are:

Atlantic Coast Fisheries Co., The Barrett Co., The Bell Telephone Laboratories, Davison Chemical Corp., Distillation Products, Inc., Ethyl Gasoline Corp., Gelatin Products Co., General Electric Co., B. F. Goodrich Co., Hercules Powder Co., Inc., Leeds & Northrup Co., Merck & Co., Inc., Monsanto Chemical Co., Norton Co., Pittsburgh Plate Glass Co., Research Corp., Standard Brands, Inc., Standard Oil Co. of California, Standard Oil Development Co., The Texas Co.

Since the conferences have now been provided a permanent home, a Policy Committee has been set up so that the whole project may be guided with the maximum wisdom. . . . The committee expressed considerable dissatisfaction of one custom in use, i. e., in having the order of the applications determine the order of selection. . . . To distribute the attendance among a wider number of institutions and bring about a more just representation, it was voted that . . . those interested in attending one or more of the conferences be instructed to send their request for attendance to the director on or before March 10.* Each applicant must state the institution with which he is connected and the type of work in which he is most interested. . . .

All requests for attendance or any additional information should be addressed on or before March 10* to the director of the conferences, Dr. Neil E. Gordon, Central College, Fayette, Mo.

*Reason for not printing this announcement earlier is that it was not received by *Instruments* until March 2. We knew about the conference but not about the March 10 "dead-line." We hope it will not be too late for *you!*

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THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

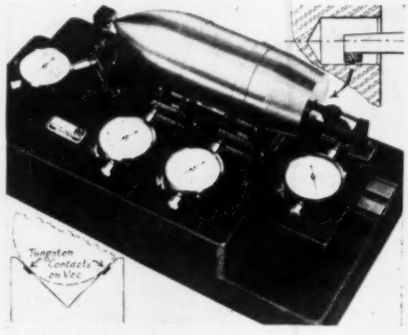
Analytical Weights

A new line of precision analytical weights designated by the trade name "Permas" are machined from an alloy containing approx. 20% chromium and 26% nickel.

This alloy is extremely hard, corrosion-resistant, non-magnetic and requires no lacquer to protect its mirror-like finish. These weights are available to meet National Bureau of Standards specifications for Class S, Class S2, and Class S Certified weights.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

Shell Concentricity Gages

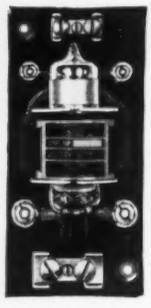
Announcement is made of a series of multiple-dial-indicator type gages for checking concentricity of projectile diameters of practically any size or type. Illustrated is



"Model 205 B-84" for 75-mm. M-72 semi-armor-piercing shot. The projectile is located in the vee block on the body diameter, with which other diameters must be concentric. Points at which the projectile contacts the vee block are faced with tungsten carbide to prevent wear. Projectiles up to approx. 14 lbs. (the weight of 75-mm. shells) can be rotated manually with comparative ease. Each dial indicator is equipped with a pantograph spring unit which protects the indicator from abuse, and at the same time contributes to the accuracy and furnishes an adjustment for contact with the shell. Each pantograph unit is equipped with an adjustable guard which prevents damage to the pantograph point if the gage is carelessly loaded. This particular gage is also equipped with a sliding indicator and pantograph unit, which contacts the fuse hole or tracer cavity and inspects its concentricity with the outside diameter (See small sketch). A greater or lesser number of diameters, and larger or smaller sized shells and projectiles can be checked on other gages of this series.—*Federal Products Corp., 1144 Eddy St., Providence, R. I.*

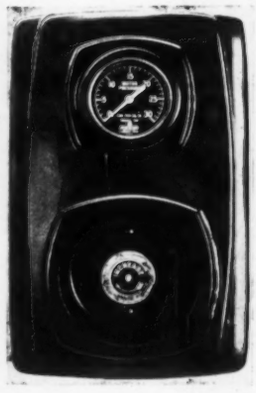
Mercury Plunger Relay

"H-B Silent Mercury Plunger Relay" has been completely redesigned and improved with three important gains: (1) Metal cap and support frame that held mercury tube were eliminated, thereby releasing strategic metals for the war. (2) Mercury tube was made secure by a single metal band which gives twice the stability of previous design. (3) Area for terminal fastening and connecting was tripled, thereby eliminating danger of tube breakage and simplifying installation. Relay has been tested to 10 million operations without a failure, has only one moving part, is available for either a.c. or d.c. Rated at 30 amperes, 110 volts, 1 hp. Listed under Reexamination Service of Underwriters' Laboratories, Inc.—*H-B Electric Co., 2536 N. Broad St., Philadelphia, Pa.*



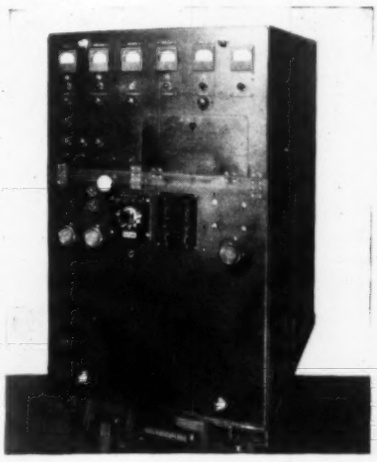
Remote Valve Control Unit

New unit for manual control of remote valves, dampers and other pneumatically operated equipment, harmonizes in appearance with rectangular case for maker's recording and controlling instruments (see *Instruments*, Dec. 1941, page 343). When Unit is flush-mounted, its front surface is 7/16" from instrument panel surface and, as its setting knob and pressure indicator are recessed, there are no protruding parts to suffer accidental bumps. Specifically designed for dead-end service, Remote Valve Control Unit will dependably hold reduced pressures to values within narrow limits. Although most commonly used as its name suggests, it is equally useful in other applications, such as setting of control points of distant instruments, or adjustment of positioning or pressure-producing pistons, located in inaccessible points. It is practical for operation over distances up to 1000 feet.—*The Foxboro Company, Foxboro, Mass.*



Mass Spectrometer for Gas Analysis

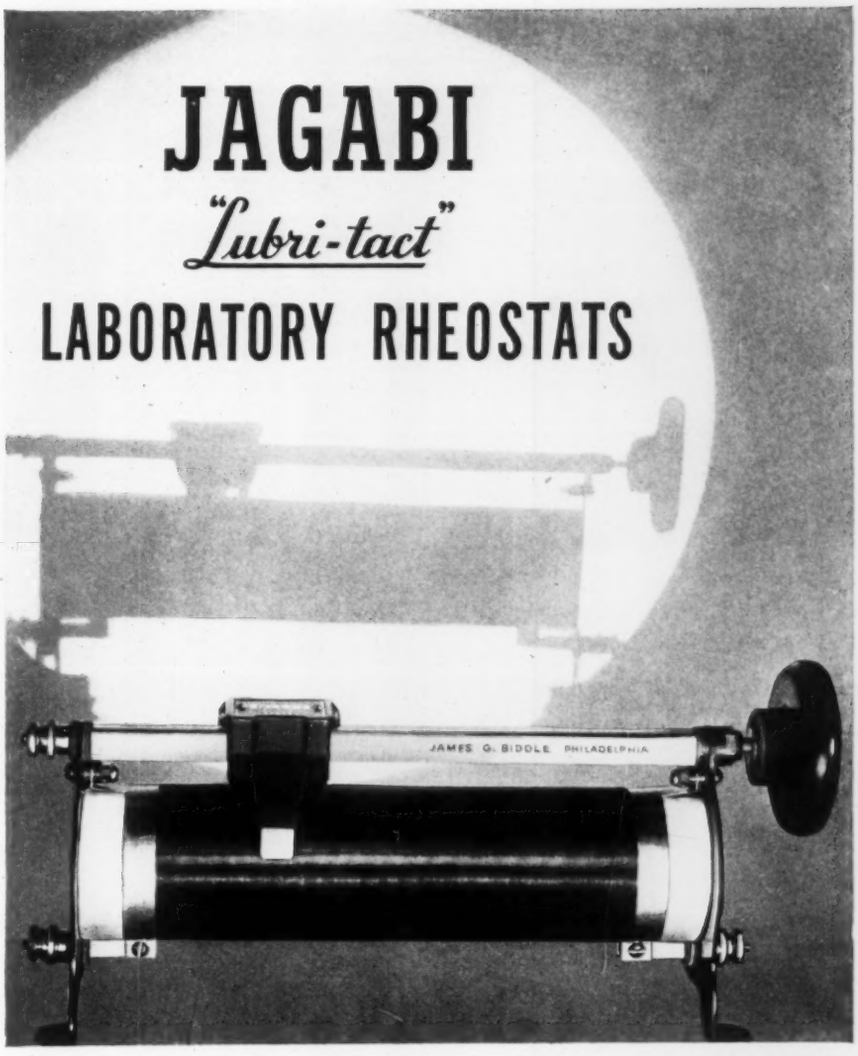
For industrial research, refineries, and chemical plants, new mass spectrometer is essentially a high-vacuum tube containing electrodes, filament, slit system, and an



electron collector. The gas or vapor to be studied is subjected to bombardment by a narrowly defined beam of electrons of the order of 10^{-6} amperes. Gas pressure in ionization chamber where bombardment takes place is about 10^{-4} mm. of mercury or lower. Ions thus formed are accelerated through two narrow parallel slits in two parallel plates at a potential difference of 100 to 1000 volts. Ions emerge from second slit as a narrowly defined beam of nearly homogenous energy. This beam is then deflected by a uniform magnetic field designed to sort the ions according to their mass-to-charge ratio. Thus the spectrometer gives directly information about the relative abundance of different kinds of molecular ion fragments formed when molecules of a particular kind are struck by electrons of known energy. For quantitative indication of the gas to be measured, the ions strike a metal cup connected to ground through a high resistance. The voltage developed across this resistor is fed to the grid of an electrometer tube. This amplifies the current so it can be read with a sensitive galvanometer. In its pilot form the spectrometer has already been used successfully in studying patterns of organic molecules and in determining the purity of gas samples. Sensitivity in the case of air is one part in 100,000. Separation of mass 108 from mass 109 has been made. Panels are hinged for accessibility to all parts. Only outside connections required are 110 volts a-c. and water connections for cooling the pumps.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

American-made Lens Tissues

Superior to the Japanese types heretofore generally used, Ross Optical Lens Tissues are said to represent a contribution to laboratory technique for keeping lenses, optical instruments, polished glass, metal and plastic surfaces perfectly clean. Unlike Japanese lens tissues, Ross Optical Lens Tissues are specially processed, non-linting, non-abrasive, of high tensile strength and highly absorbent of oil and moisture. It is said that they will not disintegrate or crumble under the severest manipulation. Smooth surface of paper tends to repel gritty dust particles and prohibits them from becoming embedded. Lens makers such as Bausch & Lomb and others have tested and approved this new type of lens tissue. Tissues are packed in pliofilm pouches that keep the tissues dustproof and waterproof at all times. Two sizes: "Standard" contains 100 sheets 3" × 5"; "Economy" size contains 300 sheets 4¼" × 5".—*The Emil Greiner Co., 161 Sixth Ave., New York City.*



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The name "*Jagabi*" stands for some 30 years of experience in design, construction and use of wire-wound tubular rheostats, manually operated. "*Lubri-tact*"* is our latest improvement—a lubricated sliding contact, giving smooth adjustment and long life.

Four sizes—76 different ratings and a variety of special types. Reasonably prompt delivery—depending on priority rating.

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Write for illustrated Bulletin 1705-I

*Trade Mark Reg. U.S. Pat. Off.

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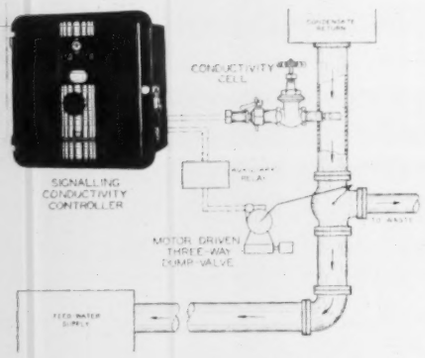
1211-13 ARCH STREET *Electrical and Scientific Instruments* PHILADELPHIA, PA.

Automatic Condensate-purity Signalling Controller

New "Signalling Controller for Automatic Testing of Condensate Purity" is designed to provide industrial steam plants "at exceptionally low cost" with dependable pro-

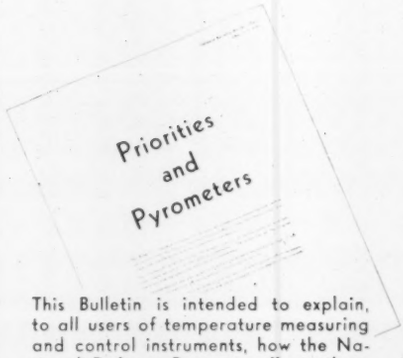


tection against damage caused by contaminated condensate. Measurement of condensate purity is performed continuously, by measuring the conductance of a continuous sample. Measuring circuit is an a-c. bridge employing standard resistors as in maker's conductance recorder, but this new simplified equipment uses an amplifier and relay instead of a galvanometer. As a controller, new instrument commands a motorized three-way valve in the condensate line to dump impure condensate. It is available also as a non-controlling instrument which warns the operator by operating external warning bells or lights. Both the controlling and the non-controlling models, however, are provided with two front-of-case signal lights: the green light flashes as long as condensate purity is above allowable limit and the red light flashes as soon as an excess of contaminants appears in the condensate. To adjust instrument for use, operator simply sets a calibrated dial and a temperature compensator. Equipment is quickly and easily installed, operates from any 115-volt a-c. line. Instrument mounts flush in panel. Its only moving parts are relay contacts. *Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*

Aerial Camera Mount

[EDITOR'S NOTE: Technical details beyond the following (which has been published) are for authorized persons only. Therefore we do not publish any illustration.]

Designed to speed up and increase the efficiency of aerial photography and reconnaissance in both the commercial and military aviation fields, new "Model MA-1" Camera Mount is in effect an automatic leveller and remote control, with three primary functions: (1) Elimination of the routine duties of the aerial cameraman, (2) Providing for remote control of the camera from any part of the survey or reconnoitering craft, and (3) Increasing the accuracy of aerial surveying. Newly-perfected mount allows for the placement of an aerial camera on any part of the airplane inaccessible to an operator. Being automatic, mount provides for greater accuracy in aerial photography than would be the case if similar pictures were taken through manual effort. Cameraman now can act as navigator. This in turn takes a burden from the shoulders of the pilot, who is enabled to concentrate on his flying. Automatic levelling is accomplished by means of photocells which are adjusted in such a way that, should the camera get off level more than a quarter of a degree in any axis, the motor controlling that axis immediately brings the camera back to true level. The timer for controlling the interval between exposures is an integral part of the camera mount, thus eliminating the necessity for more than one wire running between the control box and the mount proper.



This Bulletin is intended to explain, to all users of temperature measuring and control instruments, how the National Defense Program affects these instruments, their purchase, use, maintenance, and the replacements necessary.

The information given points out the present scarcity of various materials and lists other materials which can be used as substitutes. The properties of the original materials and the substitute materials are compared.

Recommendations are also given on maintaining present equipment so that it will operate with maximum efficiency and give uninterrupted service.

This information is given in accordance with our policy of exerting every effort necessary to further the intelligent application and use of temperature instruments in the interests of our nation's defense.

This New Defense Bulletin is important to you. Write for your FREE copy Today.

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Test Temperatures With Confidence

● THE choice of leading flight test engineers, Model 70-PO potentiometer-pyrometer likewise pleases research experts, production and maintenance men. They say it's a "natural": Thermocouple lead resistances may vary. Ambient temperature may rise or fall beyond standard cell limitations. There's built-in ruggedness against

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vibration. Temperatures are read directly, and CONFIDENTLY, as fast as couples detect change. No standard cell; and little or no balancing operation. For your temperatures of —200 to +3000°F. send for Bulletin 540-70-PO, today.

Also, try J-B-T for pyrometers, resistance thermometers, and accessories, mentioning your application.

J-B-T INSTRUMENTS, INC.
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Split-core Current Transformer

New Annis Split-core Current Transformer, for quickly testing power circuits, obviates need of opening the circuit in question, whether it is carrying load or not. To take

a reading, connect instrument to transformer's secondary terminals and close its separable core around cable or bus. Accuracy of new transformers is said to be practically independent of tightness of closing magnetic core. By reason of right-angle interleaved core construction (shown in illustration) the separable core may be left open as much as $\frac{1}{4}$" from "closed" position, without appreciably affecting instrument readings. This feature permits measuring both watt and ampere loads at sufficiently high accuracy for all general testing. New transformers also operate instruments drawing heavy volt-ampere loads such as recording ammeters and wattmeters. When transformer is closed over a conductor as illustrated, there is a choice of three primary current ranges; 150-300-600 amps, secondary current being 5 amps. If conductor passes through the opening twice, full-scale primary current ranges are 75-150-300 amps. If three times, primary current will be 50-100-150 amps. All three methods of connecting the transformer are equally accurate. Transformers are compensated for a 10-va. instrument burden, an average for recording instruments. Due to inherent ratio stability, other instrument burdens may be used with a slight reduction in accuracy. Other primary current ranges (up to 1000 amps), instrument burden compensation, as well as the furnishing of ratio and phase angle curves are available on special order. For maximum accuracy, however, transformers should be ordered, compensated for their proper instrument burden. Windings are tested at 2500 volts to ground for one minute. Transformers may be used on circuits of any voltage provided conductor is properly insulated before placing transformer in position. Opening through transformer case is $1^{9}/_{16}" \times 3^{1}/_{8}"$. Engraved terminal boards of black Bakelite with brass secondary terminals. Hinged magnetic yoke furnished with lock pin, allowing transformer to be sealed "closed" during test. Transformer weighs 12 lbs., is easily carried by strap leather handle. Protective case of aluminum, finished with black wrinkle enamel. Delivery schedule averages two weeks; orders should carry priority ratings.—*R. B. Annis Co., 1101 N. Delaware St., Indianapolis, Ind.*

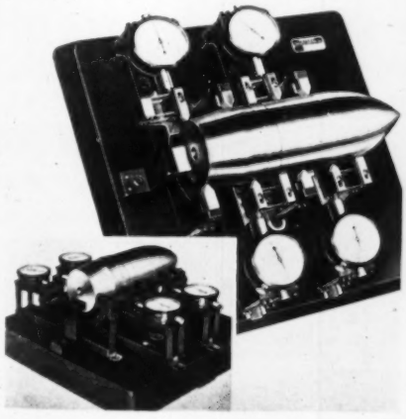
Portable "Colorimeter"

New "Laimetron Model 400 Photoelectric Colorimeter" is said to be characterized by ruggedness, simplicity of operation and low price. It is built into a wooden housing with

cover and carrying strap, so as to be used in the laboratory as well as in the plant. It works from any a-c. or d-c. 110-volt outlet. Always ready for immediate readings, it is designed to meet the requirements of practical colorimetry. It is said to offer all the advantages of the photoelectric instrument over the visual comparison instrument. —*Photovolt Corp., 95 Madison Ave., New York City.*

Shell Diameter Gages

Announcement is made of a series of multiple-dial-indicator type gages for checking several diameters independently of one another on one projectile. Illustrated is



"Model 236 B-95" for checking four diameters on the 75-mm. M72 semi-armor-piercing shot. Its effect is "the same as if four operators checked these four diameters with four individual single-purpose gages." Each indicator with its opposite anvil is a separate and integral unit, which adjusts itself independently of any other indicator. Indicators do not contact the shell directly but through pantograph spring units which protect the indicators and make adjustments easier. Each pantograph unit is equipped with an adjustable guard which prevents damage to the pantograph point if the gage is carelessly loaded. The projectile is located in the vee block. Points at which the projectile contacts the vee block are faced with tungsten carbide to prevent wear. Shells and projectiles up to approx. 14 lbs. (the weight of 75-mm. shells) can be rotated manually with comparative ease. End view shows the independent mounting of each indicator unit; only one unit is shown in this view. — *Federal Products Corp., 1144 Eddy St., Providence, R. I.*

IN the victory March of U. S. industry there is no place for equipment that bogs down. So that always-appreciated ability of Askania Control to keep right on going *without* adjustment and tinkering looms bigger than ever today. This characteristic is INHERENT. The exclusive Askania Jet Pipe Principle not only means greater accuracy and sensitivity of control; it also means greater simplicity that is carried out in precision-built units which are giving an almost incredibly trouble-free control of pressure, flow, proportioning, and combustion in every branch of industry.

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1605 South Michigan Ave.
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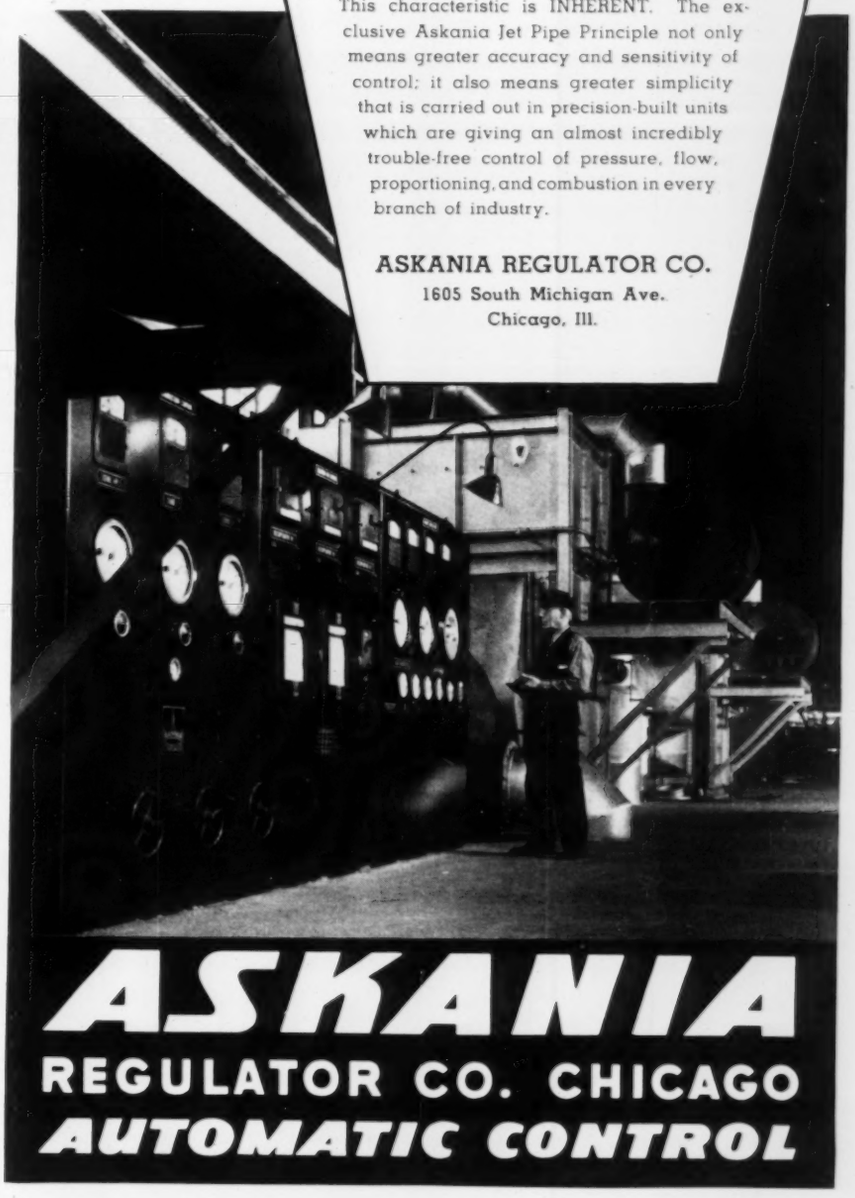

ASKANIA
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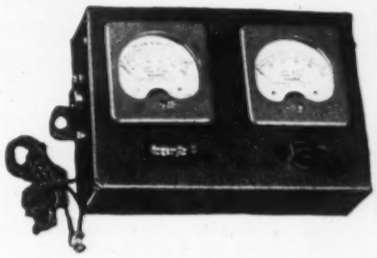
AUTOMATIC CONTROL



TRU-VAC
VACUUM GAUGES
(PIRANI TYPE)

Shown at left is meter box of our model No. 6 gauge.

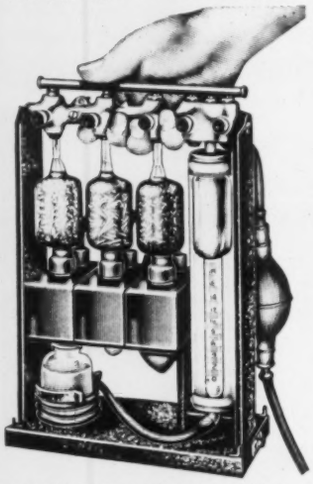
This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

CONTINENTAL ELECTRIC CO.
GENEVA, ILLINOIS

Industrial Gas Analyzer

New "Industro" Gas Analyzer, a modernized Orsat for determination of CO_2, CO and oxygen, is light, compact, leakproof and easy to operate. Glass stopcocks and glass manifolds as well as leaky metal valves have been eliminated. Apparatus consists of three glass absorbing pipettes, each of which has two parts, the glass bulb filled with copper turnings to provide surface for the reagent and a hard rubber reservoir for the reserve absorbing solutions. All burettes are American made and



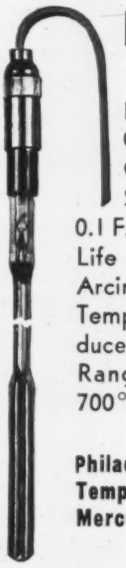
calibrated for industrial control laboratories. "Shock-proof" crystal-clear molded plastic water jacket almost entirely removes risk of breakage. Leak-proof closed system is based upon new Burrell Ball Valve which makes a positive rubber-to-glass seal. Operation is simple: turning of the knob applies pressure to a rubber sleeve in which a glass ball is pocketed, opening a channel for the gases to pass through. When the pressure is removed a positive gas-tight seal is immediately formed. Analyzer is graduated to 21% in 1/5%, is available with or without metal carrying case.—*Burrell Technical Supply Co., 1942 Fifth Ave., Pittsburgh, Pa.*

Elapsed Time Meter

New total hour meter is designed to check production and machine tool life in industrial plants where time studies are made. Embodying a six-digit cyclometer register (instead of usual five-digit) meter consists essentially of a synchronous driving motor, a gear train and six numbered wheels. Housing is standard 3½" instrument case. The motor operates at 600 rpm on a 115-volt, 60-cycle circuit. Synchronous operation is not affected by voltage variations from 75% to 125% of rated value. Life-time bearing lubrication is provided by oil storage reservoir. Gears are precision, machine cut and gold-plated to resist corrosion. To operate, the motor is connected in parallel

with the apparatus of which total hours of operation are to be measured. Motor circuits are closed when the machine operates, causing the synchronous motor to run continuously. Resetting to zero or any value is accomplished by removing the case and disengaging the number wheel shaft. The wheels can then be set to any desired reading.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

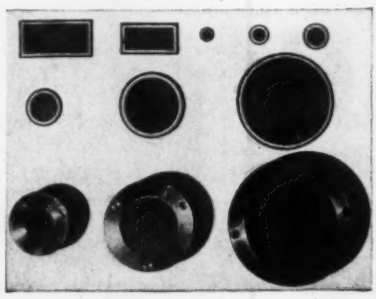
Philadelphia Merc-to-Merc Thermo-Regulators Feature



Mercury to Mercury Contacts : Increased Contact Capacity : Sensitivity within 0.1 F. Exceptionally Long Life and Stability : No Arcing : No Oxidation : Temperature Lag Reduced : Temperature Ranges adjustable to 700°F.

Philadelphia Merc-to-Merc Temperature Controls and Mercury Plunger Relays

The Philadelphia Thermometer Co.
915 Filbert Street -:- Philadelphia
WRITE FOR CATALOGUE
No. 104.
Oldest Thermometer Manufacturer in Philadelphia



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Great variety of sizes and shapes.

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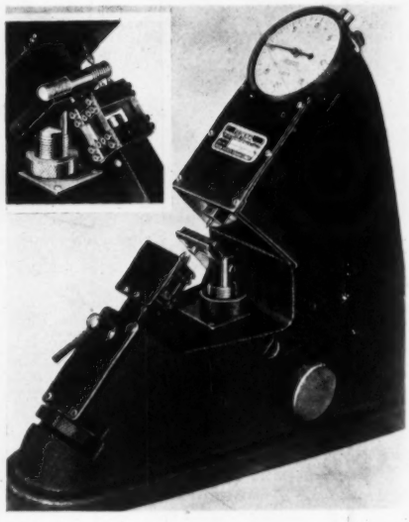
Colorimeters Electronic Timers
Reflectometers Photometers
Fluorescence Meters

Photoelectric Blackout Illumination Switch

New "Photoswitch Blackout Switch" is said to present the most economical, reliable, and foolproof method for permitting illuminated billboards, store window displays, and other time-switch-controlled illumination to remain in operation in districts where blackout regulations are in effect. It is located on the billboard or in the store window which is to be operated; and is aligned with the nearest street lamp. When this centrally controlled street lamp is turned out, the switch responds and turns off the illumination which it is controlling. It has been formally approved by the blackout committees of large cities, and adopted by outdoor advertising concerns. It operates from a supply of 115 volts A.C., and controls in its output 20 amperes at 115 volts. This will not be affected by momentary flickering of the street lamp, and is independent of ambient light conditions. Other types are available for d.c. operation.—*Photoswitch Inc., 21 Chestnut St., Cambridge, Mass.*

Pitch Diameter Gage

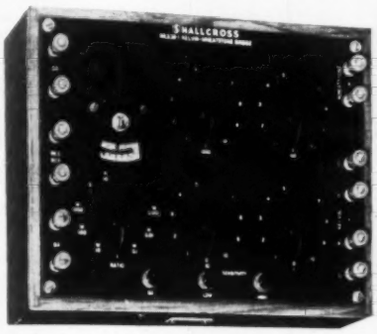
New "Model 45 B-80" incorporates the three-point method of pitch diameter inspection. Results obtained are equal to those obtained by the 3-wire method of measuring used in checking the accuracy of threaded plug gages and other precision screw threads. One reason is that the two lower ball locating points are free to adjust themselves laterally, independently of any variation in lead; and that the distance between these two points can be adjusted for different thread sizes. Lower unit is adjustable to



take various thread diameters; upper sensitive contact point, as well as lower locating points, are all spring mounted and are free from friction. Inspection within 0.0002" is quite possible. There are no sliding or rotating points to cause error. Backstop is adjustable three ways: vertically, laterally and angularly. It is possible to set it accurately back of the work and also so as to allow for heads, shoulders or other obstructions.—*Federal Products Corp., 1144 Eddy St., Providence, R. I.*

Wide-range Bridge

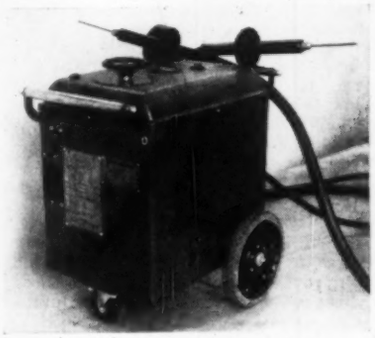
Combining in one instrument the features of both the Wheatstone and the Kelvin Bridge, new "No. 638-1 Kelvin-Wheatstone Bridge" has an effective range from 0.00001 ohm to 11,000,000 ohms. By using a source of current of considerable capacity such as a single cell of a storage bat-



tery), resistances as low as 0.00001 ohm may be detected and measured. Rheostat arm consists of four decades, variable in 1-ohm increments. Ratio arm has two sets of multipliers. The set designated "W" is for use in Wheatstone Bridge measuring; the other set ("K") is for using Kelvin Bridge method. Built-in galvanometer has deflection of 1 mm/microampere. A more sensitive external galvanometer may be used.—*Shallcross Mfg. Co., Collingdale, Pa.*

Insulation Test Set

Especially designed for testing insulation of Diesel-electric locomotives and other railroad electric equipment, new portable insulation test set is available in ½ and 2-kva ratings; includes as a unit a high voltage transformer, a means of regulating the test voltage, and the necessary overload and overcurrent devices for complete protection. For operation on 120-volt single-phase 60-



cycle supply, the ½ kva set is rated at 0 to 1500 volts or 0 to 3000 volts full capacity at 1500 volts maximum when operated in parallel and 3000 volts when used in series. It provides adequate testing facilities for Diesel-electric locomotives up to 600 hp. The 2-kva set has ratings at 0 to 3000 or 0 to 6000 volts and is recommended for testing heavier locomotives. High-voltage testing transformers for both sets are air-cooled. Secondary windings are designed for series or parallel to make available two voltage ratings. Voltage supply is received at the set through a breaker with thermal overload element for protecting the set from excessive overload. An instantaneous trip over-current relay is also provided to remove test voltage in case of test piece failure. Test voltage is regulated by a control knob operating a variable voltage transformer to give smooth potential rise. A push button control station in the handle of one test lead facilitates rapid production testing. Detachable composition castors are provided if desired.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

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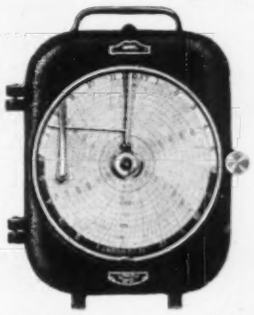
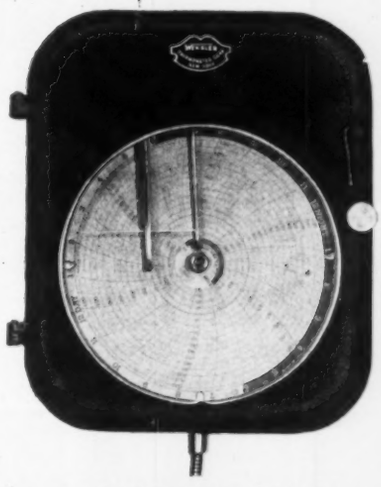
At Your Service!



Left:
Portable Recorder
6 inch Chart
24 hour Clock

Right:
Dial Thermometer
In 3½, 4, 4½, 5 and
6 inch Dial Sizes

Catalog 115
Type 103
Bronze Case,
Glass Front,
Industrial



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Furnished with 6", 10" or 12" Charts

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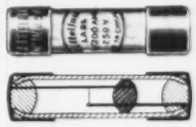
TERS RADIO AMPLIFIERS FRAC. H.P. MOTORS MAGNETS AIRCRAFT SOL

Standard Equipment USES
LITTELFUSES
"Quicker than a Short Circuit"



Littelfuse Locked Cap Assembly (U. S. Pat. No. 1922642). Positively locks cap to tube. Hermetically seals filament. Protects fuse, and prevents loss of cap with markings.

FOR UTMOST PROTECTION—MONEY-SAVING ECONOMY

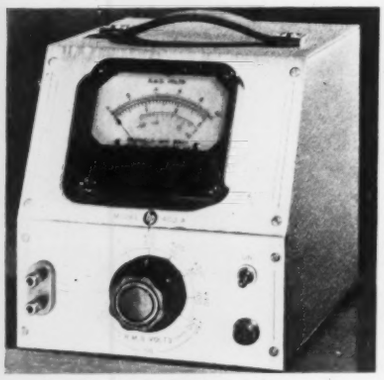
Cap Assembly only one of several LITTELFUSE FACTORS — not "equivalents." Littelfuse construction means *added* mechanical strength—*added* resistance to fatigue—*added* vibration life.

INSTRUMENT FUSES for meters 1/200 amp. up. Hi-volt ranges, 1/16 amp. up. All types Littelfuse for aircraft, radio, auto, etc., and mountings. Send for complete catalog.

LITTELFUSE INC. 4759 RAVENSWOOD AVE. CHICAGO, ILL.

Vacuum-tube Voltmeter

With New "Model 400A" Vacuum-tube Voltmeter, it is said that measurements up to 1 megacycle are now as simple as measurements with the usual multi-range instru-



ment at d-c. New instrument may ordinarily be used with no precautions whatsoever; no adjustments to make or check before taking a reading; high input impedance will not affect circuit being measured; "large" overload will not damage instrument; accuracy is "excellent because waveform errors and turn-over effect are minimized." Model 400A has a frequency range from 10 cps to 1 Mc. Nine voltage ranges are provided with full-scale sensitivities from 0.03 volts to 300 volts. Voltage scale is linear and a decibel scale based on 600 ohms and 1 milliwatt is provided. Reading is independent of line voltage and tube characteristics. Instrument is said to be excellent for all types of a-f. work, particularly valuable at the present time for carrier current, supersonic measurement, television, and measurements throughout broadcast field. While primarily a laboratory instrument, it is said to be extremely simple in operation and will save valuable time in production testing. Available for delivery with priority in 30 days or less.—*Hewlett-Packard Co., 481 Page Mill Road, Palo Alto, Calif.*

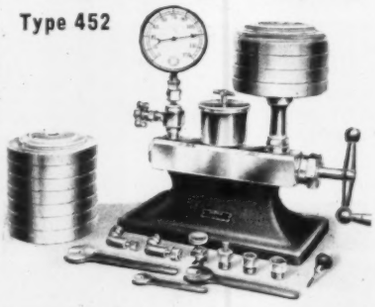
Insulation Tubing for Low Temperatures

New transparent tubing, known as "Transflex," with excellent resistance to brittleness down to —50°C., has been developed especially for aircraft flying at high

altitudes; but its physical properties including toughness and rubber-like qualities make it useful for a wide variety of other industrial and electrical applications. Example, transparency permits quick location of wire breaks and ready identification of wires. "Transflex" is a "Fibronized" tubing available from Size No. 14 to ⅝" I.D. Its flexibility is apparent from photograph; its tensile strength is 3000 lbs./in.², dielectric strength (for wall thickness of appro 0.020"), 850 VPM when dry and 815 VP when wet; water absorption, 0.4% weight after 24-hour immersion; Wem Oil Test (48 hours at 100°C.), not attacked; allowable continuous operating tem perature, 150°F. (66°C.).—*Fibron Div., Irvington Varnish & Insulator Co., Irvington, N. Y.*

AMTHOR Dead Weight Pressure Gauge TESTER

Type 452



Modern design and construction puts this rugged precision instrument in a grade above the ordinary dead-weight testers.

Made in eight ranges, to 3000 lbs. maximum.

We guarantee 1/10 of 1 percent accuracy in each range.

The Type 452 is designed for simplicity and compactness. It incorporates the newest refinements and improvements. Adapters and tools are supplied, as well as either carrying case or protecting cover.

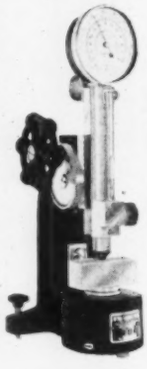
Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems. Drop us a line today.

Amthor Testing Instrument Co., Inc.

49a Van Sinderen Ave. Brooklyn, N. Y.

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 35 years.



In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

•

Illustrated bulletins free.

The Shore Instrument & Mfg. Co., Inc.

9025 Van Wyck Ave., Jamaica, N. Y.

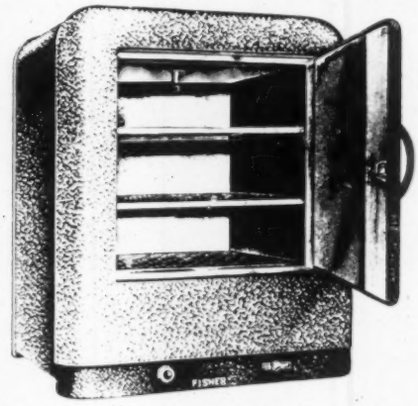
Watthour Meter Protector

To reduce lightning damage to watthour meters and appliances connected to 120/240-volt exposed secondary circuits, new meter protector, "Type AO," is a two-pole porous

block lightning arrester with a 175-volt line-to-ground rating and a 240-volt line-to-line rating. Gap breakdown on 60 cycle circuits is 800 volts r.m.s., and gap breakdown on impulse is 2000 volts crest. Discharge capacity is 10,000 lightning surge amperes. Protector elements consist of a 1" diam. porous block with a series gap of flat electrodes, separated by a mica spacer and held in firm contact by a spring plate. The two single arrester elements are mounted in a housing of Prestite, a new high-grade porcelain impervious to moisture. Mounting plate is the common connection for the two poles and, when installed, is grounded. Porcelain and coverplate mount with two screws in any standard condulet. Assembly is then covered with a gasket-sealed cover for outdoor service and a non-gasket cover for indoor service. The condulet is located above or below a meter, and each pole of the arrester is connected to the "hot" wires. The common connection point, the mounting plate, of the protector is grounded to the neutral of the circuit. This method of connection causes the lightning surges to discharge to the ground neutral wire and avoids damaging the current and potential coils.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Constant-temperature Oven

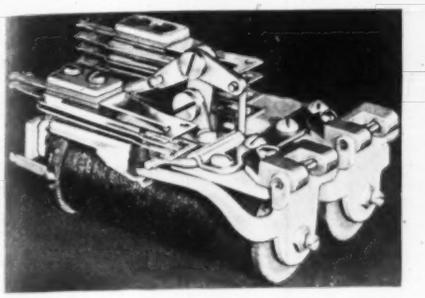
New "Isotemp" Oven embodies structural features, insulation and heating advantages which provide uniform temperature throughout heating chamber. Temperature uniform-



ity of ±1°C. throughout the oven, and a maximum variation of temperature of ±0.5°C. in a 48-hour test, are claimed. The oven is 18½" wide, 21½" high and 17" deep; it has a range of 75° to 200°C. and is available for 110 volt or 220 volt alternating current only.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

"Start-Stop" Relay

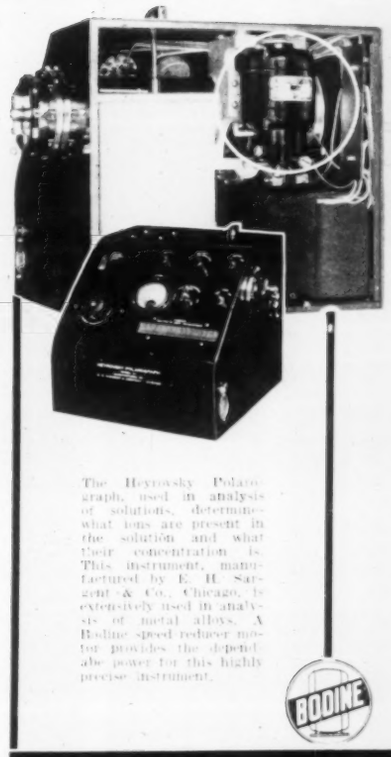
For remote-controlled starting and stopping of radio transmitters and receivers, mirage pumps, etc., a new "start-stop" relay, known as "Type 19," operates and releases over two wires, with a common return. Typical operation is by means of a two-way key, which is thrown into one position to operate contacts on relay, and thrown into the other position to release



the contacts. Relay opens its operating circuit immediately upon operation; thus, operating current is consumed for only about 0.1 second. The release circuit is similarly opened upon release. With its low operating power requirement, Type 19 relay combines exceptionally positive operation, it is said. Unique electro-mechanical locking arrangement used is said to be proof against false operation or release even under extremely severe conditions of shock. Operation is unaffected by any normal temperature changes: laboratory tests indicate dependable operation over the range of temperatures from −30 to +55°C. (−22 to +131°F.). Dependable control operation is further assured by providing twin contacts of precious metal on all contact springs. Relay can be supplied with a maximum of 18 springs for control purposes.—*Automatic Electric Co., 1033 W. Van Buren St., Chicago, Ill.*

Automatic-focus Lens

Although the living eye, with its elastic lens, automatically focuses objects at varying distances, optical engineers had doubted practicability of many ingenious proposals to accomplish this purpose in a photographic lens. Now, however, a four-element motion picture lens is announced by B&L in which one double-concave element is electronically oscillated on its axis by means of a special cell mounting developed by P. Stanley Smith, a New York radio engineer. New lens is confined to a distance of 0.3 mm. in its axis movement but the oscillations are at the rate of 23,200 times per minute, thus continuously altering the focus so that all objects are uniformly in register from four feet to infinity. Although all objects are slightly softer in focus than with lenses of a fixed focal length, many photographers regard this as an improvement. Smith, following the work of Dr. Ludwig Dieterich, an Austrian-born engineer who patented a mechanical method for vibrating a lens element, designed an electronic method of achieving this purpose and has successfully incorporated the lens in a motion-picture camera which it is believed will offer greater flexibility in motion-picture photography and direction. At present actors must work within a chalk line necessitated by focal range of camera; lighting must be rearranged for each new focus, cameras reset, and distances taped. The new Electroplane Camera, with a lens which keeps all moving objects in perpetual focus, holds the promise of a solution to one of the chief limitations in motion-picture photography. B&L engineers state emphatically that the new oscillating lens could not be incorporated in hand cameras. —*Bausch & Lomb Optical Co., Rochester, N. Y.*



The Heyrovsky Polarograph, used in analysis of solutions, determines what ions are present in the solution and what their concentration is. This instrument, manufactured by E. H. Sargent & Co., Chicago, is extensively used in analysis of metal alloys. A Bodine speed reducer motor provides the dependable power for this highly precise instrument.

Precision Speed-Reducer Motors

for all kinds of instruments

Motor driven instruments of all types, whether used in routine work or for special research jobs, all require a driving motor of the utmost reliability. These instruments depend upon the motor to provide accurate, dependable operation without danger of failure. That is why so many manufacturers have chosen Bodine Motors to power their instruments.

Bodine precision-built motors are available in more than 3,000 standard specifications for use in motor-driven machines and instruments. A bulletin describing these motors will be furnished on request. Bodine Electric Company, 2244 W. Ohio St., Chicago, Ill.

BODINE FRACTIONAL HORSEPOWER MOTORS

CONSTANT VOLTAGE

is the answer to the precision demands of

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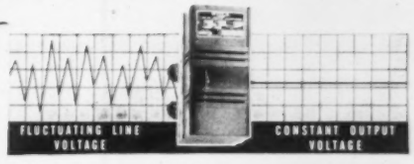

Every electrically operated INSTRUMENT employed in the production of materials of war needs CONSTANT VOLTAGE protection against line surges and fluctuating voltage levels caused by overloaded power lines. Sola CONSTANT VOLTAGE TRANSFORMERS will deliver a perfectly stabilized output voltage, even though line voltages vary as much as 30%. No moving parts. Instantaneous in action. Self-protecting against overload or short circuit.

Ask for Bulletin GCV-74

SOLA ELECTRIC COMPANY

Constant Voltage **TRANSFORMERS**

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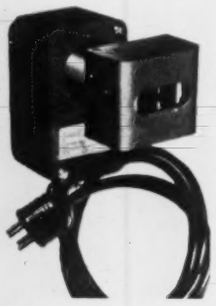
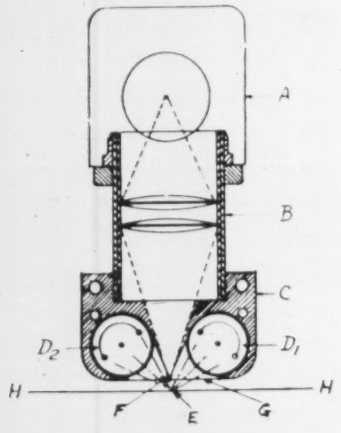
Photoelectric Scanner

New Scanner consists of a light source and two phototubes in a single compact housing, ready for attachment to any sensitive photoelectric amplifying system. It is for use wherever photoelectric control is desired from a reflecting surface 2" or less distant from unit. In operation, light from bulb in metal housing *A* passes through double converging lens in lens barrel *B*, then through aperture *F*. Highly concentrated light spot *E* strikes surface *H-H* being scanned and is reflected back into phototubes D_1 and D_2, intensity depending on diffuse reflectivity of the scanned material. A registration mark on moving paper, or the deflection of a



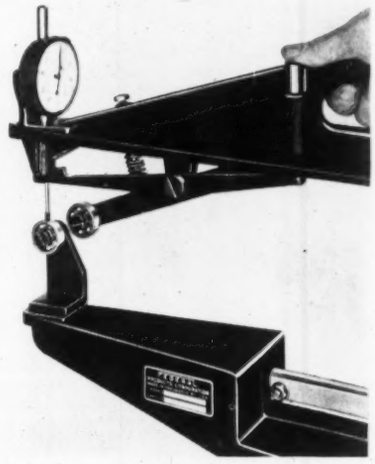


pointer, into spot *E*, will cause a change in the illumination reaching phototubes D_1 and D_2, whose response to this change is transmitted through co-axial cable to a remote amplifier, making possible the control of auxiliary electrical devices. Thus, new Scanner, obviates need for separate phototube and light source assemblies. Its small size (casing *C* measures $2\frac{1}{2}$" × $2\frac{1}{2}$" × $1\frac{1}{2}$", and casing *A* $3\frac{1}{2}$" × $2\frac{1}{4}$" × $2\frac{1}{4}$") allows mounting in restricted spaces. Lens system requires no adjustments. Unit is sufficiently flexible to operate in conjunction with any standard sensitive amplifier, although an amplifier specifically designed for this service (maker's "Model 668") is available.—*United Cinephone Corp., Torrington, Conn.*

Wall Thickness Gage for Demolition Bombs

New "Model K P-96" is a portable thickness gage for checking wall thickness of demolition bombs. Roller bearing lower anvil and roller bearing pressure unit on

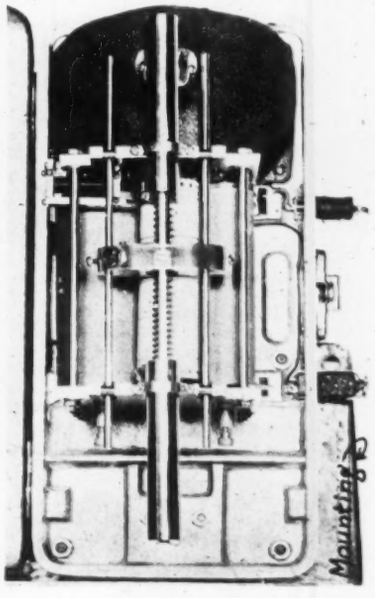
upper arm facilitate handling of gage. Upper roller unit has sufficient tension to hold lower roller anvil firmly in contact with the inside surface of the bomb. Indicator contact point (made of tungsten carbide) is raised by pressing plunger in front of foremost hand grip. Interchangeable steel slide, along lower section, guides the shell up to the locating stop. Made in any size to suit requirements. Specifications: Graduated 0.001"; (indicator Model DSIS, F.J.); dial



0-100; range, 1"; indicator has double dial and tell tale hand; depth of throat, 33.3"; other lengths and sizes can be furnished.—*Federal Products Corp., 1144 Eddy St., Providence, R. I.*

Aircraft Accelerometer

Specifically designed to eliminate from the record of acceleration the effects of higher frequency vibrations of airplane under test, new R-S Low Frequency Record-



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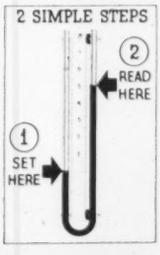

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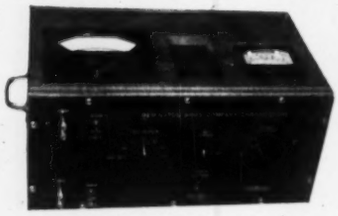

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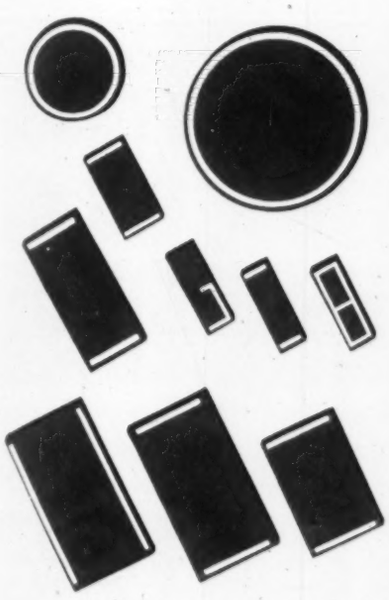

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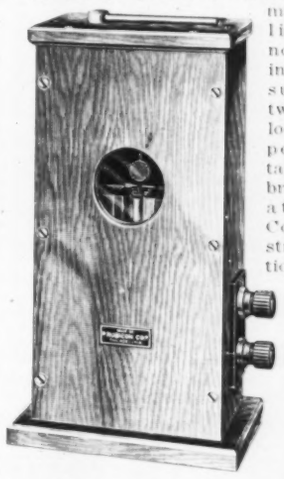

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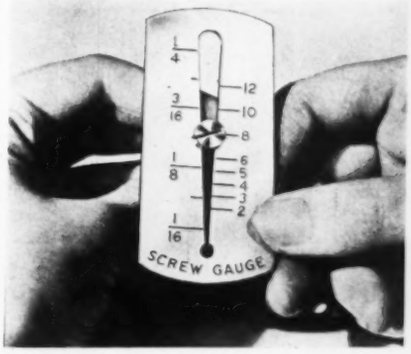

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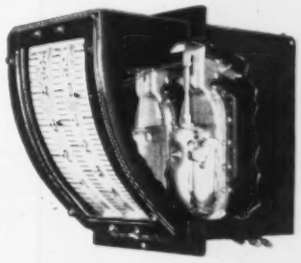

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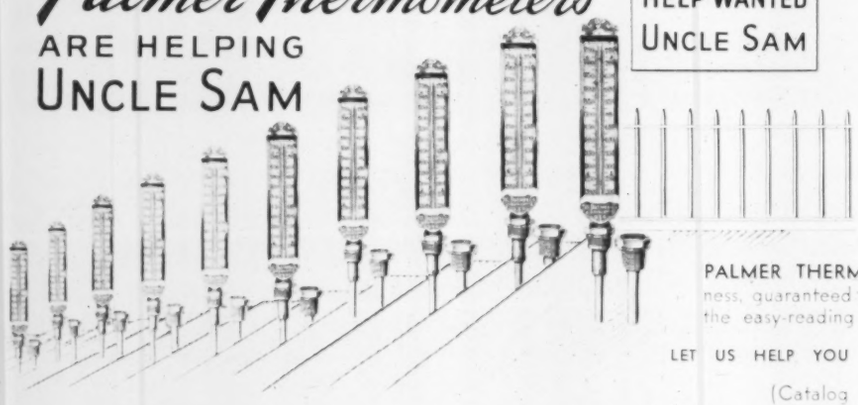

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Selection and Installation of Flow Meters*

By RAYMOND E. SPRENKLE

Mechanical Engineer, Bailey Meter Co., Cleveland, Ohio

INTRODUCTION

FUNDAMENTAL factors enter into the proper selection of flow meters, as is the case in the solution of any other engineering problem. These factors are not always understood clearly by engineers who are not entirely familiar with flow metering and it is the purpose, therefore, of this article to point out and discuss briefly some of the most important considerations entering into a wise choice of meters measuring fluid flow.

Before we take up these factors it is in order to illustrate the importance of the subject by seeing how many services around a steam generating plant need flow meters. Fig. 1 shows applications of metering and control equipment in a typical power-process steam plant and, while this diagram does not apply exactly to any actual plant with which the reader may be associated, it is hoped that it may be of some assistance in pointing out some possible applications which might otherwise have escaped the reader's attention. All the M symbols in this diagram represent flow meter applications; the P symbols represent pressure; T temperature; D draft; L level; S Smoke Recorders; and C Control points. For the purpose of this article, however, we shall confine our remarks to flow meter applications.

In the steam generation cycle, one of the most important points of flow measurement is that of feed water to the boiler, point M11. Steam generated by the boiler is an equally important metering point and this should be combined relatively with air flow through the boiler for practical application as a combustion guide, and as a factor in automatic combustion control processes, C1 or C3. Then follow in order, the measurement of steam flow to the back pressure turbine, point M2; to the reducing station, point M3; to the mixed pressure turbine, point M4; to processes which are represented in this diagram by steam flow to digester, point M5, and to the low pressure cooker, point M6. Steam flow to the feed water pump, point M7; to the steam accumulator, point M8; from each extraction point of the mixed pressure turbine; the condensate flow from the mixed pressure turbine condenser, point M9; the feed water pump output, point M10; and the make-up water flow, point M12, are also application points of much value.

Undoubtedly, in each individual plant layout the reader would be able to find other points to which meters should be applied in order to know just how efficiently each unit of his plant is performing; so that a complete and accurate picture of the plant operation as a whole can be obtained. Even in this particular application diagram, it might be advisable to measure condensate flow from the low-pressure cooker to the deaerator, condensate from the heating system, steam flow to and condensate from the feed-water heater, condenser cooling water to or from the mixed pressure turbine condenser, and so on. It is up to each plant engineer to determine for his individual case where flow meters can be advantageously used, and then proceed to select that type of metering equipment which best suits his individual needs.

In making this selection it is necessary, above all, to choose accurate, well-designed, sturdily-built and easily-maintained equipment, manufactured by a reputable concern able and eager to give competent field service in insuring a completely satisfactory installation. A mechanically-operated meter of the inverted mercury- or oil-sealed type is usually the simplest and should be used whenever possible. However, if the distance between the primary element and the meter itself exceeds 100 feet, or if the meter must be placed above the minimum hydraulic gradient, electrically-operated meters can be used to advantage. Meters having moving parts with high torque and frictional factors, or of light flimsy construction unable to maintain factory calibration for years without excessive servicing, should be avoided.

*From the text of a lecture by Mr. Sprenkle before the American Society for Measurement and Control, Pittsburgh, Dec. 15, 1941. All illustrations for this article except Fig. 7 have been especially prepared for publication in *Instruments*.

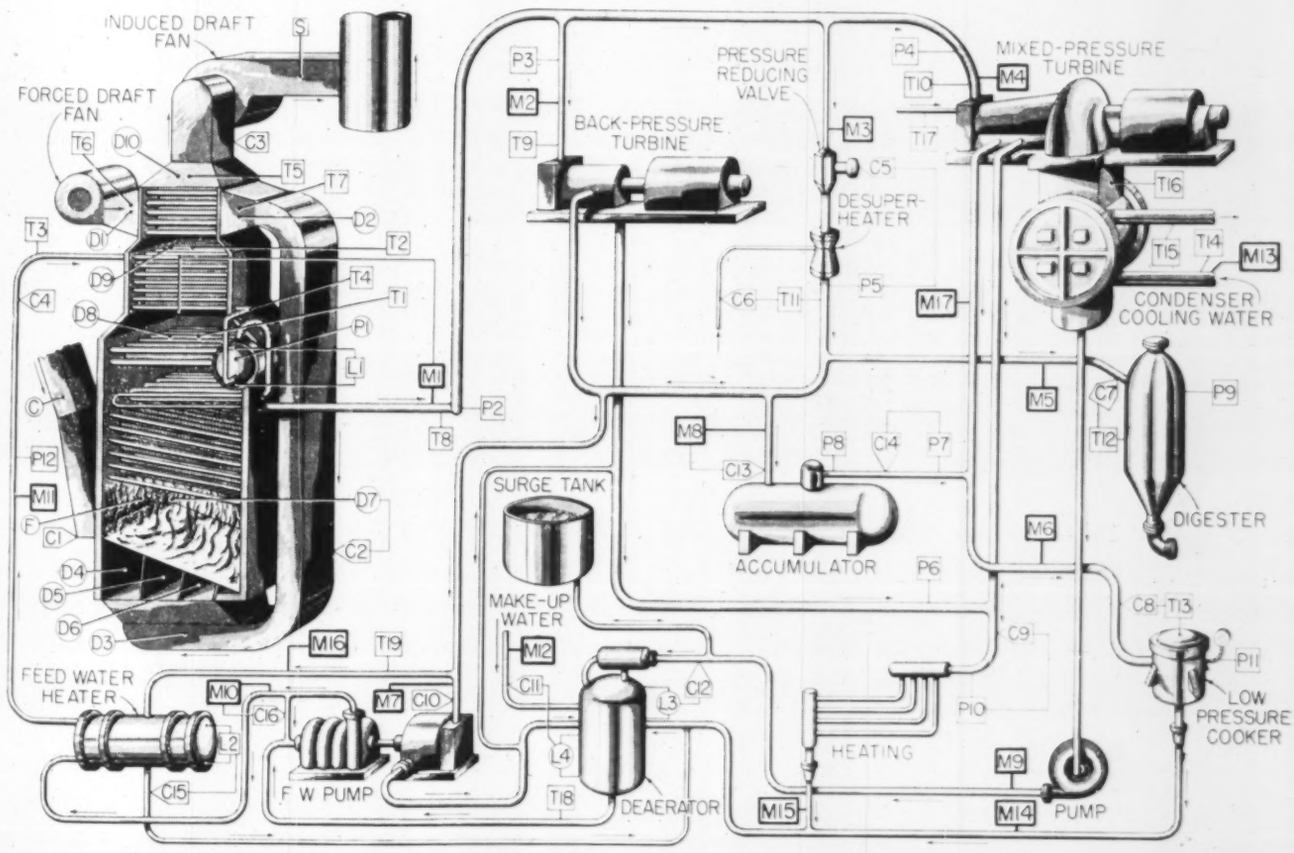

Fig. 1

FIRST STEP—DETERMINE "SIZE," ETC.

The specific choice of metering equipment involves the proper selection of two parts—the primary element, and the meter or recorder itself. These two are so closely interrelated that it is impossible to consider one completely without the other. Fortunately there is a simple index to use in evaluating the functions of each in solving any flow problem. This is the equation

$$E = \frac{W}{\sqrt{h_w \times \rho} \times D^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which:

E = the capacity factor

W = the weight of flowing fluid, in lbs./hr.

h_w = the differential head of the meter, in inches of water at 60°F.

ρ = the density of the flowing fluid in lbs./ft.^{3}

D = internal pipe diameter, in inches

This equation is used for liquids, gas, and air flow. For steam flow, it can be written

$$E = \frac{W}{\sqrt{\frac{h_w}{\text{sp.vol}}} \times D^2} \quad . \quad . \quad . \quad (2)$$

where the specific volume of the steam is expressed in cubic feet per pound.

To solve either of these equations, it is necessary to know or to estimate the maximum rate of flow expected. In this connection, meters used to measure gas and vapor flows usually read in terms of cubic feet. It is thus necessary to convert this volume flow into pounds per hour by the following:

$$W = (\text{ft.}^3/\text{hr.}) \times \rho \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The maximum meter differentials, h_w, for steam and liquid flow measurement are 13.25", 53", 120", 212", and 331". For gas, air, and other vapor flows, these maximum differentials are 2", 6", 8" and 14.3". Whenever possible use the 53" for steam and liquids and the 2" for gas, air, and vapors.

The density of gas or vapor depends upon its temperature, pressure, specific gravity and percent saturation, and of liquids upon its temperature and specific gravity. The specific volume of steam can be obtained directly from steam tables.

After determining E from the above data, refer to Fig. 2. The curve marked "Orifices" gives the ratio of the orifice hole diameter to the pipe diameter corresponding to various E values, and the curve marked "Flow Nozzles" and "Venturi Tubes" gives the same relation for these two types of primary elements. Note that the Orifice curve stops at a maximum ratio of 0.85, the Flow Nozzle curve at 0.81, and the Venturi tube curve at 0.70. It is not practical to build these primary elements of ratios larger than these limits.

It will further be noted from Fig. 2 that up to a maximum E value of about 230, it is possible to use either an orifice or flow nozzle. The flow nozzle for any given E value has a somewhat lower diameter ratio, which gives it the advantage of being able to measure a higher flow rate with a meter of any given differential head size. However, the orifice is considerably cheaper, easier to install and replace in the event of a capacity or other change, and its accuracy is of the highest, because of its thorough investigation by many experimenters. The orifice, therefore, should be used whenever and wherever possible.

The interdependence of meter size and type of primary element can best be understood by considering several specific examples.

Assume that it is desired to measure a flow of 50,000 lbs. of steam through a pipe of 9.5" internal diameter, at a pressure of 100 lbs. saturated. The specific volume of 100-lb. saturated steam is 3.892 ft.^{3}/lb., and by substituting these data in equation (2), assuming the use of a 53" differential head meter, the resulting E value is 150. From the Orifice curve of Fig. 2 the ratio is 0.75, and if the proposed piping arrangement is adequate, as will be explained later, the orifice and 53" meter combination should be used.

On the other hand, if it were desired to measure 100,000 lbs. instead of 50,000 lbs. under the same conditions, then the E value would be 300. The Orifice curve does not extend above 230; therefore a 53" curve and an orifice cannot be used. By increasing the meter differential size to 120", however, the E value reduces to 200. This permits the use of an 0.82 diameter ratio orifice with the 120" meter, which in most cases will prove the most economical as well as the most desirable combination.

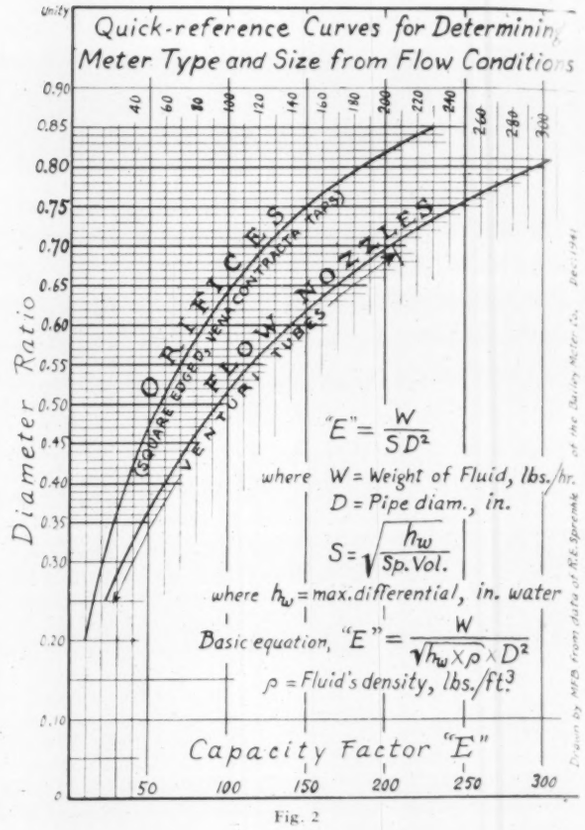

Fig. 2

Should the piping arrangement not be suitable for an 0.82 diameter ratio orifice, or if for any other reason an orifice could not be used, then the best combination would be the 120" differential head meter and a 0.70 diameter ratio flow nozzle.

Other flow conditions of capacity, pipe size, and quality of the flowing fluid might result in an E value of 450, for example, if it were attempted to use a 53" head meter and an orifice. Since this is beyond the Fig. 2 limits it is necessary to reduce the E by changing the meter head. Increasing the meter differential from 53" to 120" decreases the E value by $\frac{2}{3}$, or in this instance to 300, which is still beyond the Orifice curve but which would allow the use of an 0.80 diameter ratio flow nozzle.

If an E value of 600 were first obtained, based on a 53" meter and orifice combination, increasing the meter differential to 120" would reduce the E value to $\frac{2}{3}$ of 600, or 400. Even this is beyond both the Orifice and the Flow Nozzle curves, Fig. 2, so it would be necessary to increase the meter size to 212". Since this is four times the 53" differential, the E value will be reduced by one half, or to 300. This allows the use of a flow nozzle of 0.80 ratio.

Since it is not desirable to use a larger nozzle than 0.81 diameter ratio, it is evident at once that an E value exceeding 300 will require a larger differential head than was used to arrive at that value. If the differential head used to obtain an E value of 300 was 212", as described in the preceding paragraph, then it would be necessary to do any one of the following or any combination thereof:—(1) Increase the meter differential to 331", or

(2) Increase the pipe size, or

(3) Reduce the maximum capacity.

It will rarely be necessary to resort to the use of a meter as large as the 331" size or to follow either of the other two possibilities or combinations thereof, for *the great majority of metering problems fall within the scope of the standard 53" and 120" meters for steam and liquids, and 2" and 6" for gases and other vapors.*

While the examples above are based on the use of standard Bailey meters, the curves of Fig. 2 and the procedure outlined above are universal and apply to the use of any head meter of any manufacture and to any orifice using vena contracta pressure connections, that is, with the inlet connection one pipe diameter preceding and the outlet connection approximately ½ pipe diameter following the orifice. As such the reader will undoubtedly find these curves of value in the solution of metering problems whether the fluid is steam, water, gas, air, oil, or any other fluid capable of measurement with head meters.

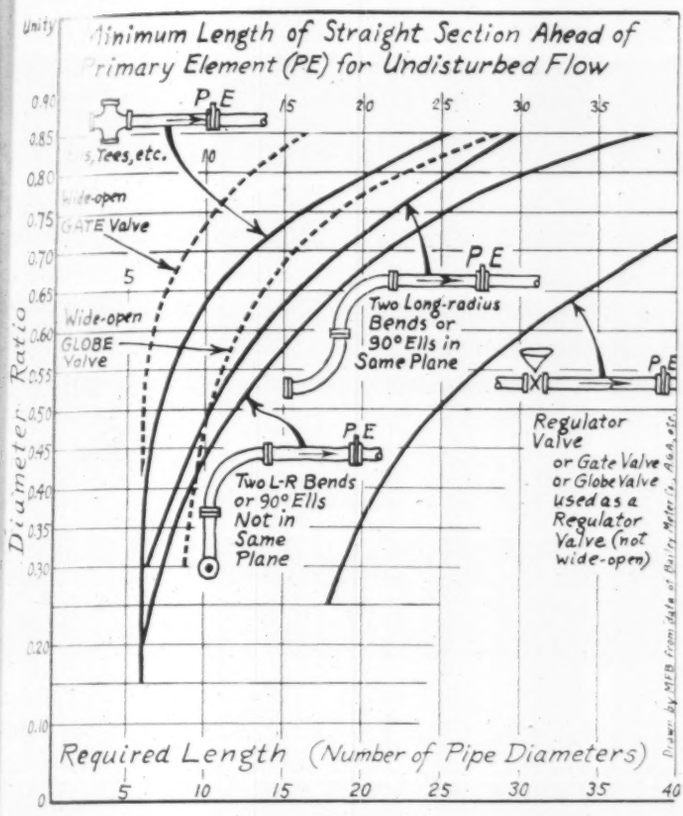

Fig. 3

ANOTHER FIRST STEP—PIPING LAYOUT

An equally important consideration is the selection of a suitable location for the primary element. In order that the orifice, flow nozzle, or Venturi tube may function in the manner anticipated by its design, the proper lengths of straight pipe must be provided for, both preceding and following the primary element.

The required lengths *preceding* the primary element, for several different piping layouts, are shown by the Fig. 3 curves. Two points will at once be apparent on examining these curves: (1) the required lengths of straight pipe increase rapidly with the diameter ratio of the primary element; and (2) as the piping arrangement proceding the straight run ahead of its primary becomes more complicated, longer runs of straight pipe are required for any given diameter ratio.

The simplest arrangement, shown in the upper left hand, may include any simple fitting such as an elbow, tee or *one* long-radius bend. The long-radius bend itself may even be considered as so much developed straight pipe, if it is preceded by at least ten diameters of straight pipe. It cannot be so considered if it is preceded by a fitting or valve (other than a wide-open gate valve), or by another long-radius bend. Thus it is not permissible to consider any combination of bends as equivalent to straight pipe, but one can consider only the straight pipe itself which follows such bend combinations. In every instance except the case of a single long-radius bend we must consider the run of straight pipe as starting with the end of the bend immediately preceding the straight run.

In view of the great importance of this matter of proper piping arrangement for accurate metering, the author urges that everyone in position to do so see to it that adequate lengths of straight pipe are provided in the beginning when the piping system is laid out, for each meter installation contemplated. Usually this is not a difficult job if these considerations are taken into account then, whereas changing the piping layout later so as to provide suitable locations is a much more difficult and expensive matter.

Many times it is necessary to use existing piping layouts which do not provide satisfactory piping arrangements, or you may be unable to provide the required amount of straight pipe in a new installation. For example, you may require a 0.75 diameter ratio orifice with a 53" head meter to handle a flow problem, in accordance with examples given above, but you may have available but 10 diameters of straight pipe on the inlet side and this is preceded by an elbow or tee. For satisfactory service, you should have at least 16 diameters of straight pipe. By increasing the head of the meter to 120", the diameter ratio is reduced to 0.64, for which size the 10 diameters available will suffice. But if the 10 diameters of straight pipe were preceded not by one elbow or tee, but by two elbows or fittings in the same plane, then 22 diameters of straight pipe would be required for the 0.75 ratio orifice. In this case it would be necessary to increase the meter differential to 120" and use a flow nozzle instead of an orifice. If two bends or fittings at 90° to each other preceded this 10 diameters of straight pipe, 25 diameters would be required, and in order to reduce the diameter ratio to about 0.43, so as to utilize the actual 10 diameters available, it would be necessary to use a 212" head meter and a flow nozzle.

Thousands of experiments by careful investigators have disclosed also that accuracy may be destroyed by altering the flow conditions too close to the primary element on the *outlet* side. A good rule for best results is to provide a straight run of pipe after the primary element equal to one-tenth of the length ahead (as determined from Fig. 3) but *never less than one pipe diameter*. These painstaking investigations have disclosed further that this general rule is modified by the nature of the fittings on the downstream side of the primary element as well as by the diameter ratio of the primary element itself. Thus the rule must be strictly enforced if there is to be a 90° ell; but a wide-open gate valve may replace the straight section. These findings are summarized in Table I.

TABLE I—FITTINGS ALLOWED ON OUTLET SIDE OF PRIMARY ELEMENT IN PLACE OF STRAIGHT PIPE

Fitting on Outlet Side	Diameter Ratio 0.20	0.30	0.40	0.50	0.60	0.70	0.80
Gate Valve							
Y-fitting							
Separator			*	*	*	*	*
Expansion Joint							NOT ALLOWED
Tee							
45° Ell							

* If Inlet Neck Is One Diam. Long

It will be noted from Table I that it is possible to install an orifice or flow nozzle at the inlet side of 45° elbows only if the diameter ratio of this primary device does not exceed 0.50. Similarly, expansion joints can be used on the outlet side only up to 0.60 diameter ratio, Y-fittings and separators up to 0.70, and gate valves up to 0.85. Naturally the better installation is made *between straight runs of pipe*, with at least two diameters following the primary element.

Straightening vanes may be of assistance in some instances where there is sufficient pipe to install them and where the line velocity, pressure and temperature conditions are not too high. As a rule, however, they are not generally recommended by us.

From the above, you will note the important place the proper location of the primary element plays in the correct *selection* of metering equipment. We cannot stress this point too emphatically. The proper location of the primary element must be made in the beginning if you expect to obtain an accurate, dependable and worthwhile meter installation. Any compromise in this direction jeopardizes the accuracy of the entire installation.

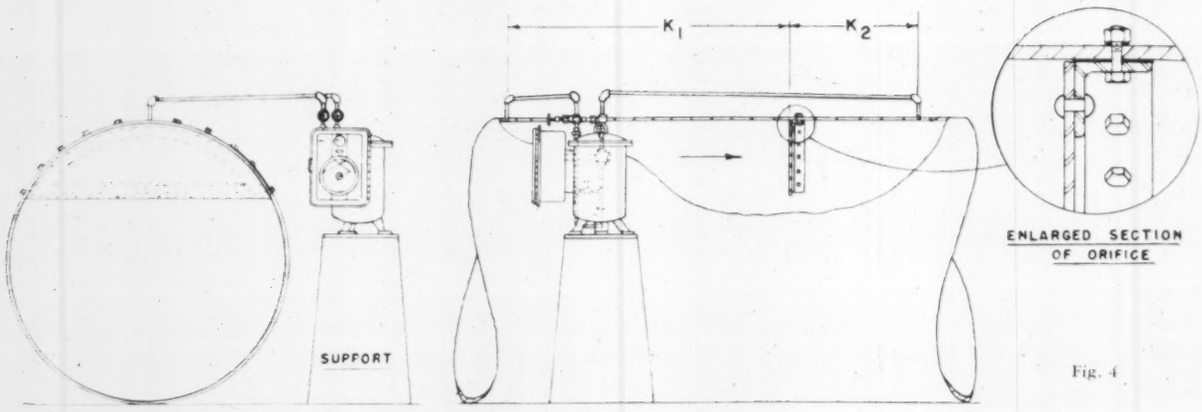

Fig. 4

SPECIAL FORMS OF ORIFICES AND FLOW NOZZLES

Mention has been made of the advisability of using orifices whenever possible. In certain types of service the orifice presents a means of flow measurement much superior to any other. For example, it is comparatively easy to install an orifice segment in the top of a large size gas main even though no flanges now exist for holding the orifice in place. See Fig. 4. Then, too, such application of the orifice permits extraneous materials such as tar, residues, blast furnace dust, etc., to be carried through and not build up deposits in the pipe ahead of the orifice. In other cases where there is a tendency for such materials to corrode or damage the orifice plate, or to foul its inlet edge with scale, tar, or grit, the orifice is much easier to remove either for replacement or inspection and cleaning. It must be remembered also that such incrustations are much less apt to form on the sharp edges of a thin-plate orifice than on the much broader throat of either a flow nozzle or a Venturi tube.

War Production priorities make it difficult to obtain forgings for manufacturing flow nozzles, because of the diverting of a large proportion of the output of forge shops into armaments. It is then all the more important to use thin-plate orifices whenever possible, especially when prompt delivery to your plant is required.

There are cases, however, where orifices cannot be used because of physical limitations. One of these is the result of using welded piping where there are no flanges available in the piping system, as is almost always the case with high-pressure high-temperature steam plants. This makes it impossible to use standard orifices or flow nozzles. So far no satisfactory means have been developed for applying special orifices to such services but a method has been designed to use special types of flow nozzles. These are shown in Fig. 5. The holding ring type (most commonly used) is held in place by a holding ring which itself is welded to the pipe line. Pins reaching through the pipe wall, holding ring, and the outer surface of the nozzle, further anchor the assembly to the pipe. The sleeve type uses a holding cylinder surrounding the flared nozzle proper and this cylinder is welded to the pipe in the plane where the pipe section holding the nozzle is welded to its adjacent section. This cylinder thus forms a backing-up or chill ring at this joint. The assembly of either type of welded-in nozzle is usually done in our shops or in those of the piping fabricator, under our supervision, so that the entire assembly, less perhaps the K_1 and K_2 pressure connections, is delivered to the job site ready for welding into the pipe.

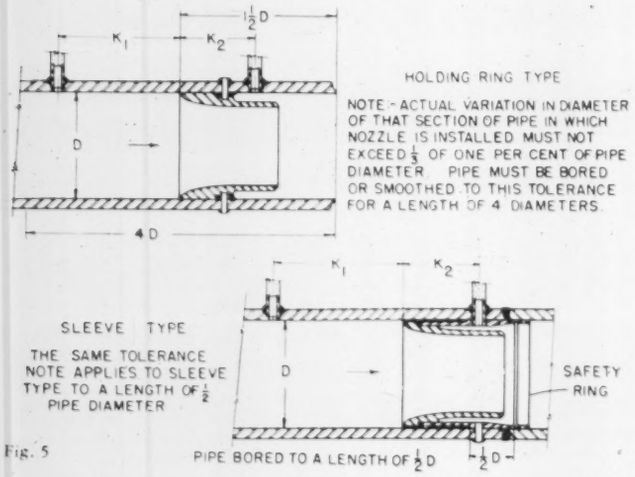
1½D
K1
K2
D
4D
HOLDING RING TYPE
NOTE - ACTUAL VARIATION IN DIAMETER OF THAT SECTION OF PIPE IN WHICH NOZZLE IS INSTALLED MUST NOT EXCEED ⅓ OF ONE PER CENT OF PIPE DIAMETER. PIPE MUST BE BORED OR SMOOTHED TO THIS TOLERANCE FOR A LENGTH OF 4 DIAMETERS.
K1
K2
SLEEVE TYPE
THE SAME TOLERANCE NOTE APPLIES TO SLEEVE TYPE TO A LENGTH OF ½ PIPE DIAMETER
D
SAFETY RING
PIPE BORED TO A LENGTH OF ½D
½D

Fig. 5

When the pipe sizes are small, for example, 1", 1½", 2", 2½" and 3", it is best to use either an Orifice Pipe, or a Flow Nozzle Pipe, as shown in Fig. 6. The primary element, as well as the K_1 and K_2 pressure connections are factory-installed so that the field installation is a very simple procedure. The inlet section of these pipes is about 15 diameters long, which is sufficient in most cases to satisfy the minimum piping requirements discussed above. The maximum E values for which these pipes can be built are given in Table II.

TABLE II

	Maximum E Values	
Pipe Size	*Orifice Pipe*	*Flow Nozzle Pipe*
1	130	175
1½	140	195
2	145	225
2½	150	245
3	160	275

The orifice and the flow nozzle are interchangeable in these small pipe assemblies, so that the capacity can easily be increased on the job, within the limits of the E values given in this table, by removing the small orifice and substituting a flow nozzle in its place. Larger changes in capacity would require a change in meter differential, or an increase in pipe size. Since the latter is usually not a difficult procedure with these small-size lines, such pipe changes can oftimes be made more economically than to change the meter to a higher head.

For metering oils, tars, black liquor, crudes, and other liquids of high viscosity, orifices of diameter ratios not exceeding 50%, equivalent to an E value of 55, should be used. Beyond this limit, there is a large change in the orifice characteristic with every change in flow rate, viscosity, and/or density which is reflected at once in the accuracy of the

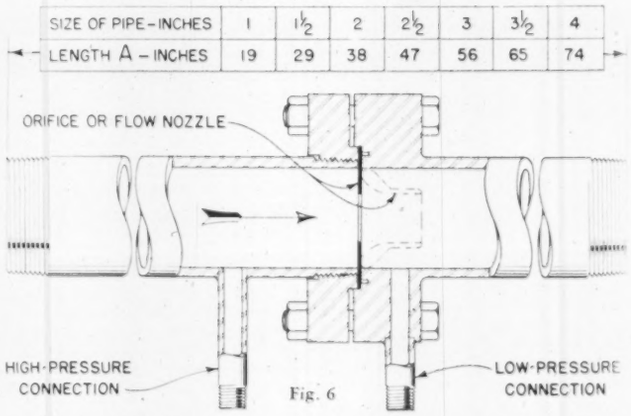
SIZE OF PIPE - INCHES | 1 | 1½ | 2 | 2½ | 3 | 3½ | 4
LENGTH A - INCHES | 19 | 29 | 38 | 47 | 56 | 65 | 74
ORIFICE OR FLOW NOZZLE
HIGH-PRESSURE CONNECTION
LOW-PRESSURE CONNECTION

Fig. 6

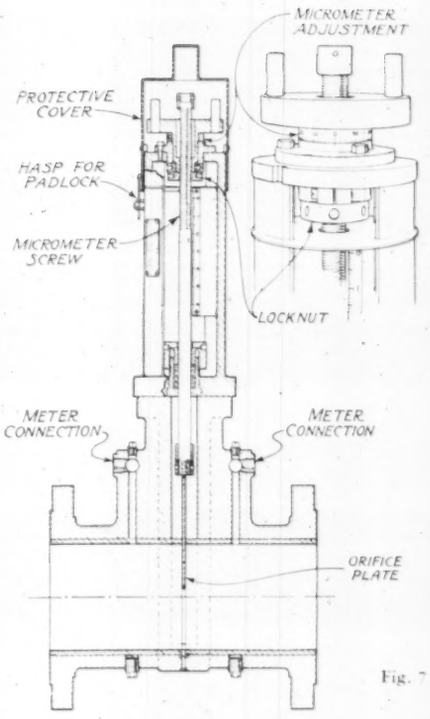

Fig. 7

meter registration. Flow nozzles or Venturi tubes can be used, but are not the preferred types because of the tendency of their throats to become rapidly fouled with residue from such fluids.

So far, our discussion of orifices has been confined to the fixed-size type, with a hole of definite size or shape which cannot, in itself, be changed without obtaining an entirely new orifice plate or reboring the old one to make the new hole diameter larger. Ordinarily such changes are infrequent and present no difficult problem. However, there are services where flow rates vary widely from season to season, from week to week, or from day to day. Frequent changing of orifices to accommodate swings in flow rate would be inconvenient if not physically impossible, especially now that peak system capacities must be maintained without shutdowns. For such conditions, the Adjustable Orifice, Fig. 7, has been designed. It has a segmental orifice plate attached to a rising stem and mounted in a specially-designed body with integral pressure connections. The orifice segment is positioned quickly and accurately by a micrometer screw adjustment shown at the top of the superstructure. The

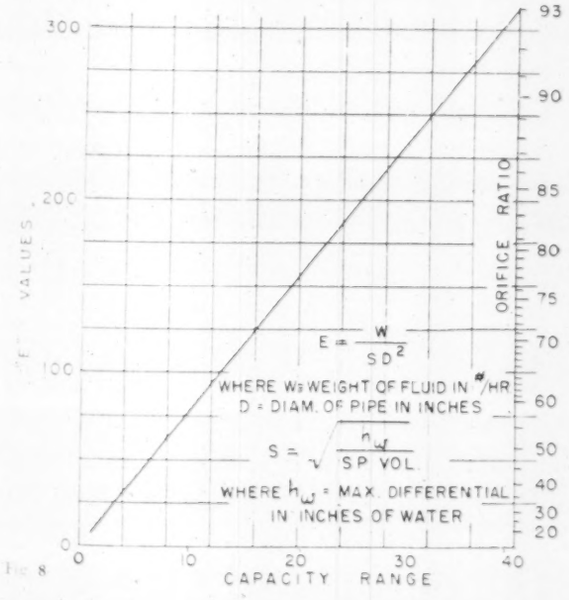

Fig. 8

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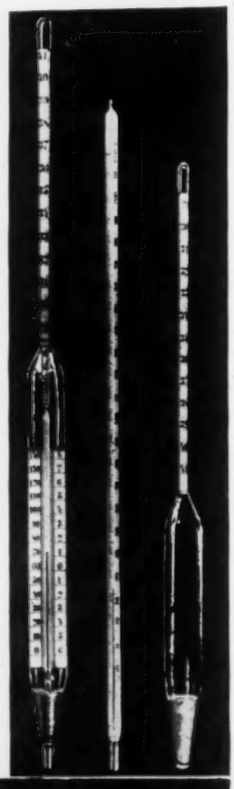

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micrometer head is graduated in hundreds, and there are 10 threads to each inch length of the stem, thus making it possible to adjust the height of the orifice segment to the nearest thousandth of an inch. Since this adjustment ranges over practically the entire diameter of the body, which is bored to the same diameter as the pipe line in which it is installed, it is possible to get a maximum capacity or flow rate adjustment of as much as 40 to 1 from the lowest to the highest possible setting. If the highest setting required for any specific job is less than the maximum possible for the orifice, the range of adjustment is of course less. Fig. 8 shows the range of such adjustable orifice adjustment for the equivalent maximum diameter ratio setting required.

For example, if the maximum setting corresponds to 0.90, the corresponding range of adjustment is 34 to 1. In other words, if this maximum required setting of the adjustable orifice corresponds to a flow of 170,000 lbs. at maximum meter reading, the minimum possible setting of the orifice would be 170,000/34 or 5000 lbs. With the maximum setting, the meter operated by the adjustable orifice would read 170,000 lbs. at its maximum and with the minimum orifice setting, the meter would read 5000 lbs. at its maximum. Since most meters record or indicate over a range of at least 4 to 1, this means in this particular example, a total accurate range of at least 136 to 1.

Similarly, the maximum possible range of accurate meter registration, using the maximum possible adjustable orifice setting would be at least 160 to 1.

Obviously, the use of this device eliminates the necessity of changing orifice plates or of using a by-pass arrangement with its attendant valves, tees and other expensive piping parts.

OTHER TYPES OF PRIMARY ELEMENTS

The Venturi tube type of primary element has been in commercial use since 1888 and, perhaps because of its long-established use, it has gained the reputation in some circles of being the most accurate primary element on the market. While its accuracy is unquestioned by the writer, attention is called to the fact that it is inherently no more accurate than any well-designed and well-made thin-plate orifice or flow nozzle when properly installed in accordance with the manufacturer's recommendations. There are places, however, where the Venturi tube does have a decided advantage over any other type of primary element.

Because of its restoring cone, the overall pressure loss of a properly designed and built Venturi tube will not exceed 12% to 15% of the differential pressure between the inlet and the throat section. In fact some manufacturers claim that this loss can be held to within 10% to 12%. Where available head is at a premium, as for example in pumping stations where every foot of water head saved represents a direct gain in power and consequently a reduction in pumping costs, the higher recovery of the Venturi may be well worth the additional cost over an orifice or flow nozzle. When fluids carrying solids or extraneous matter in suspension, as for example, sewage, and sewage sludge, are to be metered, the gradual approaches to and exit from the Venturi throat helps prevent accumulation or deposits at the throat. Clean-out valves and handholes in the venturi piezometer rings are a further means of keeping the throat from fouling. Water works and sanitation engineers therefore, favor the Venturi tube, and almost universally specify its use in these applications. In our opinion there is no particular advantage of the Venturi tube over a flow nozzle in the measurement of feed water to a boiler, since in this case the small additional pressure loss across the nozzle means little in proportion to the total pump pressure. On the other hand, the flow nozzle, even of the welding-in type, is considerably cheaper than the Venturi and therefore, is more justified economically.

There are, of course, other types of primary elements, such as Pitot tubes, Parshall flumes, cone sections or tapers, and numerous special or proprietary forms, but we cannot take the space to discuss these here. The ones we covered are the most commonly used and thus the ones which you would most likely consider for application in your own plants.

EFFECTS OF FLUID COMPRESSIBILITY

Another important point to consider when measuring steam and other vapors is the change in density of the vapor between the inlet and outlet sides of the primary element. At maximum flow, the pressure loss across a primary element designed for a 53" head meter, is 1.91 lb. The specific volume of 10-lb. gage steam is, for example, 16.494 ft.^{3}/lb. However, if this pressure is reduced by 1.91 lb. on the outlet side of the primary element by the passage of steam through it, the specific volume on the outlet side then increases to 17.778 ft.^{3}/lb. The basic hydraulic flow rate

equation used in designing primary elements assumes that the same specific volume or density exists on both sides of the primary element. If this is not the case, an appreciable error is introduced which depends upon the following five factors:

(1) The gage pressure.

(2) The meter differential.

(3) The type and variety of primary element.

(4) The diameter ratio of the primary element.

(5) The mean specific heat ratio of the flowing fluid.

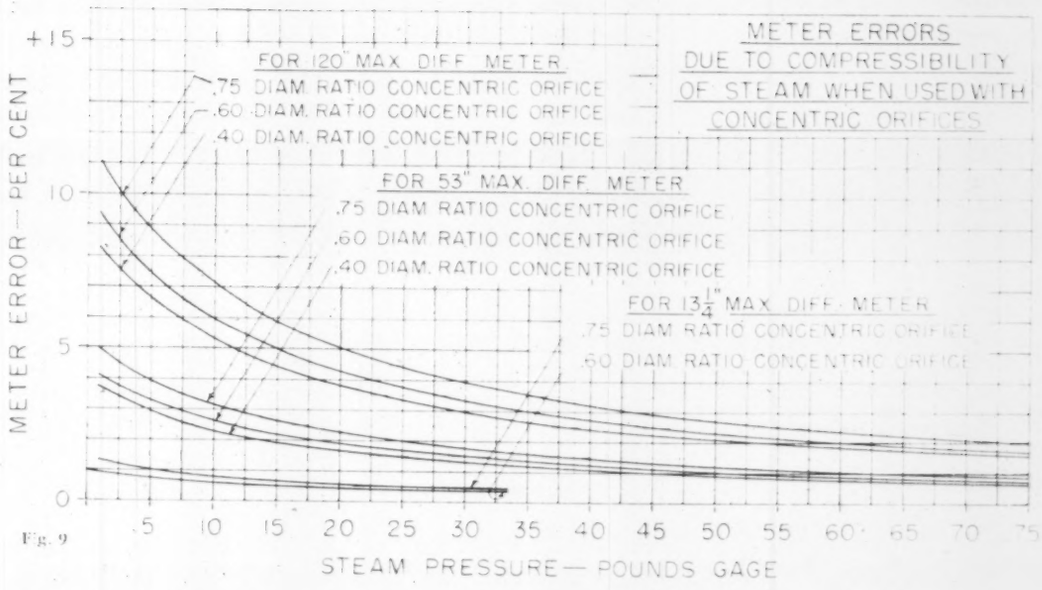
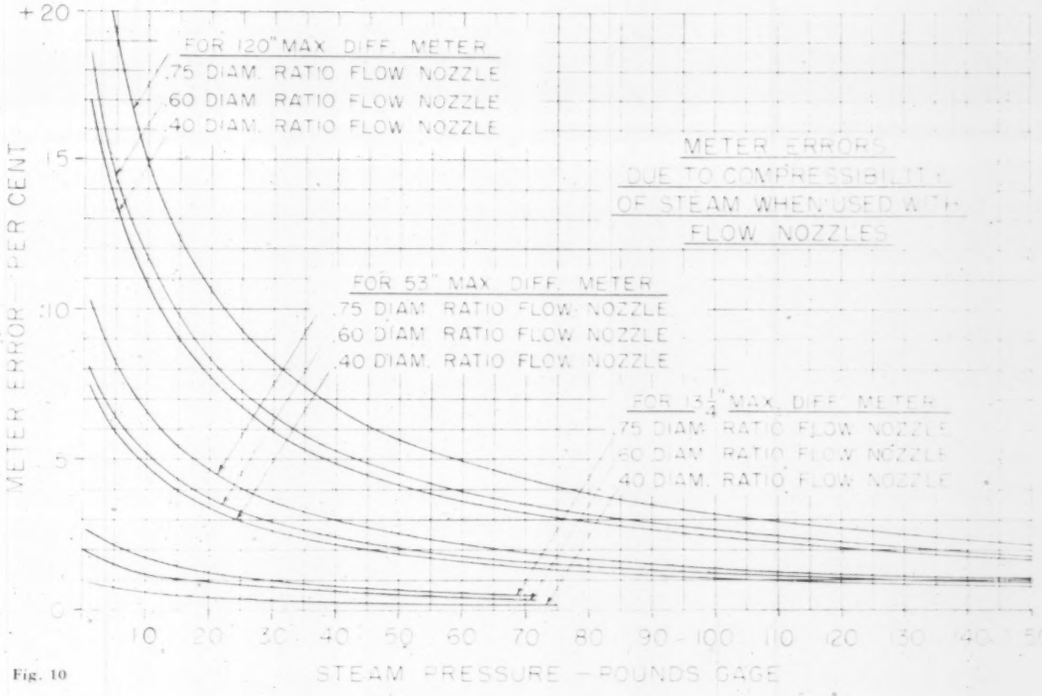

METER ERRORS
DUE TO COMPRESSIBILITY
OF STEAM WHEN USED WITH
CONCENTRIC ORIFICES
FOR 120" MAX. DIFF. METER
.75 DIAM. RATIO CONCENTRIC ORIFICE
.60 DIAM. RATIO CONCENTRIC ORIFICE
.40 DIAM. RATIO CONCENTRIC ORIFICE
FOR 53" MAX. DIFF. METER
.75 DIAM. RATIO CONCENTRIC ORIFICE
.60 DIAM. RATIO CONCENTRIC ORIFICE
.40 DIAM. RATIO CONCENTRIC ORIFICE
FOR 13¼" MAX. DIFF. METER
.75 DIAM. RATIO CONCENTRIC ORIFICE
.60 DIAM. RATIO CONCENTRIC ORIFICE
METER ERROR — PER CENT
+15
10
5
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
STEAM PRESSURE — POUNDS GAGE

Fig. 9


FOR 120" MAX. DIFF. METER
.75 DIAM. RATIO FLOW NOZZLE
.60 DIAM. RATIO FLOW NOZZLE
.40 DIAM. RATIO FLOW NOZZLE
METER ERRORS
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OF STEAM WHEN USED WITH
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FOR 13¼" MAX. DIFF. METER
.75 DIAM. RATIO FLOW NOZZLE
.60 DIAM. RATIO FLOW NOZZLE
.40 DIAM. RATIO FLOW NOZZLE
METER ERROR — PER CENT
+20
15
10
5
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
STEAM PRESSURE — POUNDS GAGE

Fig. 10

Fig. 9 shows the interrelation between these five factors for 0.40, 0.60 and 0.75 diameter ratio concentric orifices using 13¼", 53", and 120" head meters, and Fig. 10 shows the same relation for 0.40, 0.60 and 0.75 diameter ratio flow nozzles, all based on measuring steam flow.

Examination of Fig. 9 shows, for example, that a 120" head meter, when using a 0.75 diameter ratio concentric orifice would be in error 7.15% at maximum flow when measuring steam at 10-lb. gage, whereas the 53" head meter used under the same conditions would be in error but 3.15%, and a 13¼" head meter 0.8%. Obviously the 13¼" head meter is the one to use, if the resulting size of the concentric orifice does not exceed a maximum of 80% and if it fulfills the minimum requirements as given in Fig. 3. For it must be remembered that every time the maximum meter differential is decreased, the diameter ratio must be increased if the same type of primary element is used, thus increasing the required length of straight pipe on the inlet side of the primary element.

As the line pressure increases, the meter error due to the compressibility of the steam gradually decreases, until at 75 lbs. the error at maximum flow using 120" head meter and a 0.75 diameter ratio concentric orifice is about 2%. This can be cut in half by introducing a 1% correction into the orifice design so as to make this meter read correctly at approximately 70% of flow. This results in an error of minus 1% at low rates of flow and an error of plus 1% at maximum flow.

Similarly with a 53" head meter and a 0.75 diameter ratio concentric orifice, the error decreases to about 2% at a pressure of 25 lbs. and the same treatment can be given the orifice design here as mentioned above.

By comparing Figs. 9 and 10, it will be noted that the errors due to the compressibility of steam are about twice as large with flow nozzles as with orifices. In other words, errors due to compressibility do not reduce to 2% until a line pressure of about 150 lbs. is obtained using 120" meters and a 0.75 ratio flow nozzle or until approximately 70 lbs. when using a 53" head meter and a 0.75 orifice.

While the curves in Figs. 9 and 10 illustrate errors due to steam flow, similar errors due to the flow of air and other diatomic gases are about 93% as large, so that the curves serve as excellent guides regardless of the vapor being measured.

IMPORTANT INSTALLATION DETAILS

While many readers are quite familiar with the procedure of making a satisfactory meter installation under all operating conditions, we believe it would be in order to outline briefly some of the important points which need emphasis upon their being done correctly. These will cover

installations in general, then installations for the measurement of steam, water, gas and air.

General

In all cases, it is necessary to use great care in making the installation of K_1 and K_2 pressure nipples. The inside edge of these nipples should be flush with the inside of the pipe and there must be no burrs, whiskers, or broken edges on this end, as otherwise the measurement of static pressure at these points will be in error. See Fig. 11.

Care must be taken also that the primary element is installed in such a way as to be centered correctly in the pipe. If centering pins are used, they must be installed on the inlet side of the orifice. Care must be taken that no part of the orifice or flow nozzle is covered up by the flange gaskets. It is also imperative that the radiator reservoir assemblies, when used for steam and for hot water, be level lengthwise and with each other and must be maintained that way at all times.

The connecting piping between the primary element and the meter must have a slope of at least one inch per foot throughout the entire run and the entire piping system including the K_1 and K_2 nipples, valves, radiator reservoir assemblies at the pipe line must be well supported and kept free from leaking.

Steam

(1) The K_1 and K_2 pressure connections must be installed in the side of horizontal lines, except when a long-radius bend in horizontal plane precedes the run of straight pipe ahead of orifice or nozzle. In this case, the connections should be placed on top of the pipe.

(2) When the primary element is installed in a vertical line, a $\frac{3}{4}$" pipe size (or larger) bent nipple should be used in order to bring the reservoir attached to the lower connection up to the level of the reservoir attached to the upper connection. This bent nipple must be well lagged to prevent the hanging up of moisture in the nipple and thus causing a false head on the meter.

(3) The connecting piping to the meter must be made of non-corrosive materials and its slope must not be less than 1" per foot, more if at all possible to obtain it.

(4) A drop leg system of piping is recommended for all steam flow installations where the meter must be located above the primary element. The purpose of this system is to prevent the syphoning of mercury out of the meter in the event a partial vacuum is created in the pipe line at times when there may be no actual flow taking place.

(5) When the meter is mounted above the primary element, it is necessary to have sufficient pressure on the system at all flows to keep the connecting lines full of condensate. For example, a 13¼" head meter mounted 15 ft. above the orifice and measuring steam at 5-lb. pressure, could not function properly, because at maximum flow, the water in the K_2 connecting pipe would rise only to a height of 11.5 ft. instead of the required 15 ft. If it is impossible to lower the meter so that at any rate of flow the connecting piping can be maintained full of condensate at all rates of flow, then it will be best to use a Synchro-Meter system with the transmitter located anywhere close to the primary element and the receiver located at the desired elevation of 15 ft. above the orifice. Another Bailey scheme utilizes the standard mechanically-operated meter above the primary element. In this case the radiator reservoirs are located at least 5 ft. above the meter and are connected to the steam line by 1" lines which are tapped into either the top of the pipe or at an angle of approximately 45°. Drain or recirculating lines must be provided between the radiators and the orifice. This drain line is left bare, but the 1" steam line to the radiators is well lagged.

(6) When considerable dirt, mud, scale, or other impurities exist in the steam lines, it is best to install settling chambers or traps. These can be blown down periodically or as required.

Water

(1) K_1 and K_2 pressure connections should be installed in side of a horizontal pipe. They should never be installed in the top of the pipe under any circumstances, due to the trapping of air separated from the flowing fluid which in turn would cause the connecting piping to the meter to become air bound.

(2) Should it be necessary to use an eccentric or segmental orifice made flush with the bottom of the pipe so as to allow scale, mud or other impurities to be washed through, the orifice can be so installed as to have its nameplate and the K_1 and K_2 nipples at 45° from the horizontal instead of in the horizontal plane. This will still allow the orifice to be substantially flush at the bottom especially in the case of the segmental type orifice and at the same time will not place the connections directly at the top of the pipe where they may become air bound.

(3) It is desirable to have a reservoir at the end of K_1 and K_2 connecting nipples in the case of water flow measurement at temperatures in excess of 250° in order to equalize the temperatures in both connecting lines to the meter. It is also not desirable to locate the primary element in a vertical line because of the difficulty of equalizing the temperature in the bent nipple with the line temperature.

Gas and Air

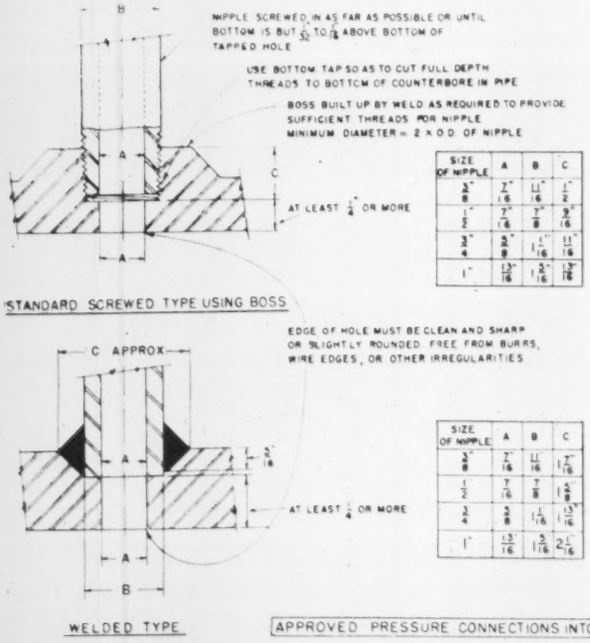
(1) The K_1 and K_2 connections should be located on the top of the horizontal piping so as to allow moisture to drain back into the main line.

(2) It is desirable to have drip pockets at the meters in the case of gases carrying moisture, dirt, tar, or other material, so as to keep these substances out of the meters themselves as much as possible.

(3) The connecting piping should so run as to have no pockets or dips which would collect water which would render the meter inaccurate.

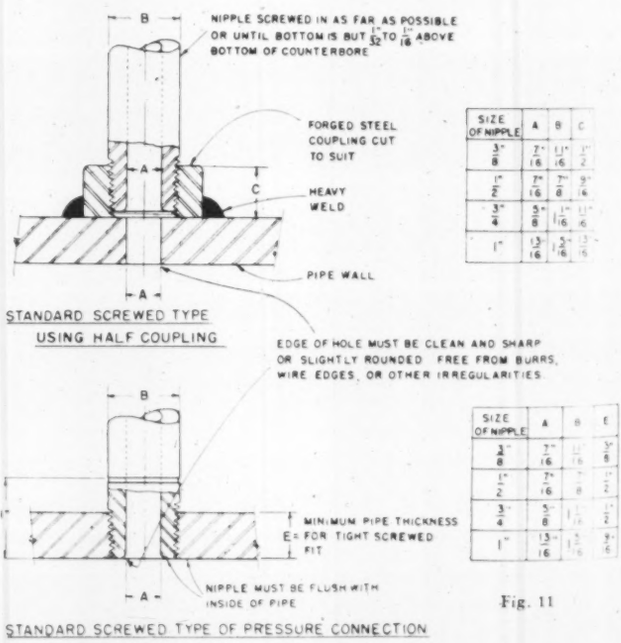
(4) Sometimes it is desirable to make the connecting piping 1" or 1½" size instead of the usual ½", especially where the meter is a long way from the orifice, and where maximum sensitivity of metering is desired.

If your meter selection has been wisely made in accordance with these basic engineering considerations, and if actual installations have been carefully made in a workmanlike manner, your meter installation should pay handsome dividends, in terms of accurate knowledge of what is going on in your plant, for many years to come.


B
NIPPLE SCREWED IN AS FAR AS POSSIBLE OR UNTIL BOTTOM IS BUT 1/32 TO 1/16 ABOVE BOTTOM OF TAPPED HOLE
USE BOTTOM TAP SO AS TO CUT FULL DEPTH THREADS TO BOTTOM OF COUNTERBORE IN PIPE
BOSS BUILT UP BY WELD AS REQUIRED TO PROVIDE SUFFICIENT THREADS FOR NIPPLE. MINIMUM DIAMETER = 2 × O.D. OF NIPPLE
A
C
AT LEAST 1/4" OR MORE
STANDARD SCREWED TYPE USING BOSS
C APPROX
EDGE OF HOLE MUST BE CLEAN AND SHARP OR SLIGHTLY ROUNDED FREE FROM BURRS, WIRE EDGES, OR OTHER IRREGULARITIES
AT LEAST 1/4" OR MORE
WELDED TYPE

SIZE OF NIPPLE	A	B	C
3/8"	7/16"	11/16"	1/2"
1/2"	7/16"	7/8"	9/16"
3/4"	9/16"	1 1/16"	11/16"
1"	13/16"	1 5/16"	13/16"

SIZE OF NIPPLE	A	B	C
3/8"	7/16"	11/16"	7/16"
1/2"	7/16"	7/8"	1 5/8"
3/4"	9/16"	1 1/16"	1 13/16"
1"	13/16"	1 5/16"	2 1/16"


B
NIPPLE SCREWED IN AS FAR AS POSSIBLE OR UNTIL BOTTOM IS BUT 1/32 TO 1/16 ABOVE BOTTOM OF COUNTERBORE
FORGED STEEL COUPLING CUT TO SUIT
HEAVY WELD
A
C
PIPE WALL
STANDARD SCREWED TYPE USING HALF COUPLING
EDGE OF HOLE MUST BE CLEAN AND SHARP OR SLIGHTLY ROUNDED FREE FROM BURRS, WIRE EDGES, OR OTHER IRREGULARITIES
MINIMUM PIPE THICKNESS
E = FOR TIGHT SCREWED FIT
NIPPLE MUST BE FLUSH WITH INSIDE OF PIPE
STANDARD SCREWED TYPE OF PRESSURE CONNECTION

SIZE OF NIPPLE	A	B	C
3/8"	7/16"	11/16"	1/2"
1/2"	7/16"	7/8"	9/16"
3/4"	9/16"	1 1/16"	11/16"
1"	13/16"	1 5/16"	13/16"

SIZE OF NIPPLE	A	B	E
3/8"	7/16"	11/16"	3/8"
1/2"	7/16"	7/8"	1/2"
3/4"	9/16"	1 1/16"	1/2"
1"	13/16"	1 5/16"	9/16"

Fig. 11

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New Method of Measuring Mechanical Vibrations

By H. C. WERNER

Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

HIGHER speeds and refinements in machines have given rise to a need for methods of measuring lateral mechanical vibrations with an accuracy heretofore unattainable, so that correct diagnoses of vibration troubles can be made rapidly in practice. Because of this need, Westinghouse research engineers have been studying methods of measuring vibrations and it is believed that the new method herein disclosed represents a major advance.

A vibrograph, in its simplest form, consists of a mass connected by a weak spring to a supporting frame as shown by Fig. 1A. The frame is held against the vibrating body and forced to vibrate with it. A pointer on the mass and a

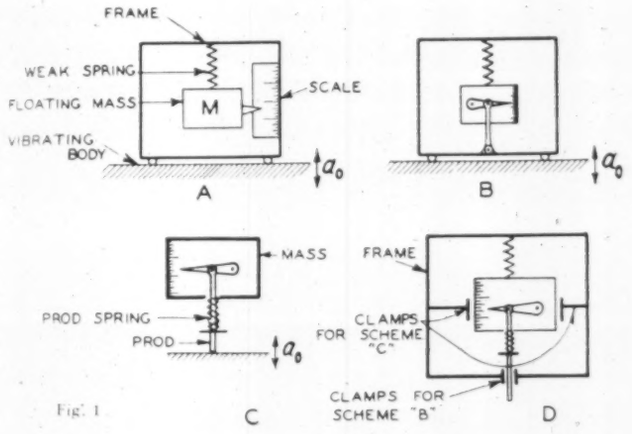

Fig. 1

scale on the frame give the relative position of the two parts of the vibrograph. To make a record of the vibration, the pointer is replaced with a pen or stylus which marks a suitable moving tape on the frame. The record is a curve showing the relative motion of the mass and frame drawn on a time axis.

The following equation* shows the relation of relative motion to frequency for the system of Fig. 1A.

$$\frac{y_0}{a_0} = \frac{(\omega^2/\omega_N^2)}{\sqrt{[1-(\omega^2/\omega_N^2)]^2 + [(2D/D_c)\ (\omega/\omega_N)]^2}}$$

where y_0 is relative motion of mass and frame
a_0 is vibration amplitude (frame)
ω is vibration circular frequency
ω_N is natural circular frequency of vibrograph
D is equivalent damping of vibrograph between mass and frame (assume viscous damping)
D_c is value of critical damping.

A typical resonance curve plotted from this equation is shown in Fig. 2B. Although the system has no special damping, there usually is enough present because of pen friction and working at the spring clamps, etc., to damp out the free vibration of the mass in a reasonably short time. From this curve it is evident that at low frequencies (near zero cycles per minute) the mass follows the frame and no amplitude is recorded. On the other hand, at high frequencies (more than twice resonant frequency) the mass is practically stationary, and a record is obtained which is close to the motion of the frame or vibration being measured. The error is given by the curve. The limitations on measuring low frequencies are therefore determined by the natural frequency of the suspension. The natural frequency should not be greater than approximately one-half the lowest frequency being measured. For this simple system there is no fundamental upper frequency limit.

*See "Mechanical Vibrations," by Den Hartog, page 69.

For small amplitudes it is impractical to make a record directly without some magnification between the mass and frame. This can be done as shown by Fig. 1B, and if the single degree of freedom is retained, the resonance curve of Fig. 2B still applies.

Sometimes it is impractical, or even impossible, to have the frame of a vibrograph follow the vibrating motion of a body. For instance, there may not be a convenient place to set or fasten the instrument, or the body may be small, and the vibration itself affected by the addition of mass (vibrograph frame) to the small body. Fig. 1C shows a scheme for a portable or hand type vibrograph which can be used for such conditions. The vibrograph mass is held in the hands, which in this case act as suspension springs, and it is only necessary that the stylus and its connecting parts follow the vibration. The prod is held against the vibrating

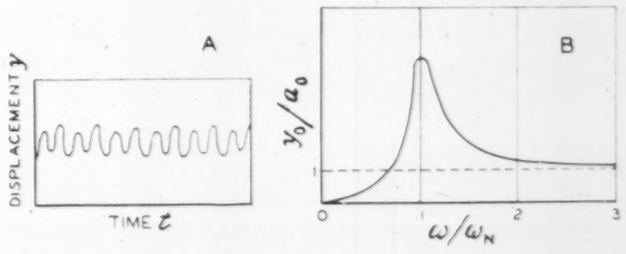

Fig. 2

body and transmits the vibration to the stylus. It is necessary to have a spring to hold the prod against the body, and this spring must exert sufficient force on the prod to keep it against the body for all vibrations being measured. However, the frequency range of a vibrograph of this type is limited at both low and high frequencies. When the inertia forces of the prod and stylus parts overcome the spring force, the prod fails to follow the vibrating surface against which it is held. Although the spring must exert sufficient load on the prod, it also is desirable to keep the spring constant as low as possible since it is parallel with the suspension springs (the hands in this case) and affects the natural frequency of the mass. This system is not restrained to one degree of freedom, and it is possible to have errors introduced because of rotation of the mass. By proper design, however, these errors can be minimized.

A more universal unit (Fig. 1D) results if the systems of Figs. 1B and 1C are combined. By clamping the mass to the frame, the system of Fig. 1C is obtained. If the mass is unclamped and the prod clamped to the frame, Fig. 1B results.

With proper suspension, any of the above systems can be made to measure lateral vibrations in any direction from horizontal to vertical.

RECORDING

To satisfy the requirements of industry a method of measuring vibrations must have accurate timing and recording, be capable of measuring frequencies up to about 15,000 cycles per minute, and have provisions for making measurements seismically, as well as by holding the instrument in the hands.

A stylus consisting of a fine steel wire with a spherical end of about 0.002" radius may be used to make a record on a celluloid film.* Pressing lightly on the celluloid, the stylus causes the film to flow plastically. In moving over the celluloid surface, the stylus makes a narrow and shallow

*This method of recording has been used by the Cambridge Instrument Co.

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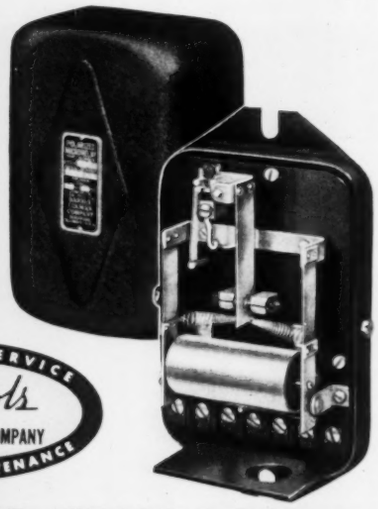

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groove which can be viewed with a low-power microscope. A celluloid ribbon approximately 0.005" thick and 1" wide is used.

Fig. 3 shows a scheme for making a record of vibrations on the film. The film is rolled up and set into the round recess provided, and the end is led up over the flanged guide roll and through the drive and tension rolls. The tension roll is mounted on a flat spring and holds the celluloid against the drive roll which is operated by a spring motor. The stylus point rests on top of the film, where the latter is supported by the guide roll. The timer stylus is directly under the main stylus and records a timing wave on the underside of the film. The main stylus arm is pivoted elastically to the main body of the instrument. The prod assem-

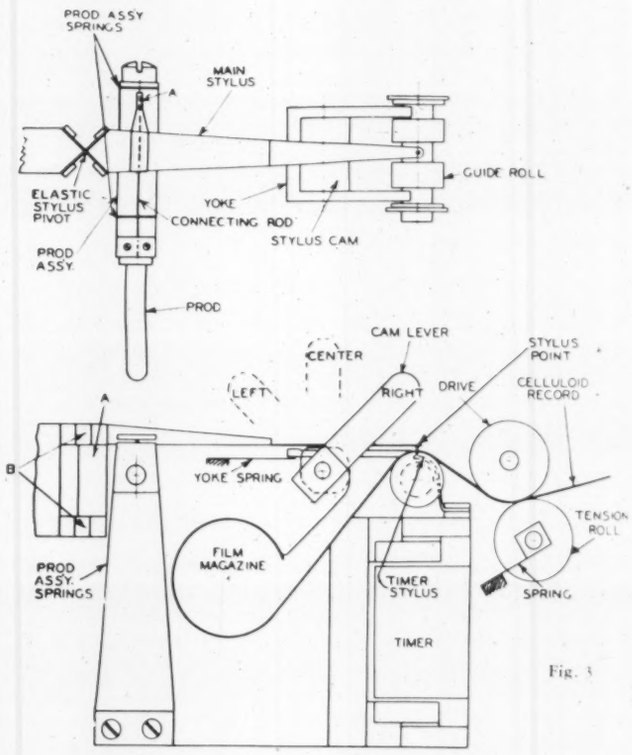


Fig. 3

bly is supported by two flat springs which serve not only as an elastic support with one degree of freedom, but also provide the necessary force to the prod so that it will follow the vibrating surface against which it is held (see Fig. 1C). These springs are designed to exert a one-pound force on the prod, and at the same time have as low a spring constant as possible (one pound per inch total). The vibrating motion of the prod is transmitted to the stylus arm through a stiff wire or connecting rod which connects these two parts. By fastening this wire to the stylus at a point A beyond the stylus arm, the wire will only deflect in single instead of double bending and can be made considerably larger in diameter from a stress standpoint. This increases the stiffness in the direction wanted.

The elastic construction of a mechanism built according to this scheme insures permanent reliability since there are no wearing parts such as would be had with pin hinges. Friction is also eliminated and periodic adjustments are unnecessary.

In order to examine the records and measure the frequencies and amplitudes, a low-power microscope with a graduated eyepiece is used. The microscope contains a flash light battery, bulb, and a reflecting mirror such that the light is directed up through the film and gives the necessary contrast between the record and the background. The records can be photographed if desired.

TIMING

For timing vibrations, a system consisting of two masses may be used. They are spring mounted to the main body in such a way that each can rotate about an axis through its center of gravity, the two axes, O_1 and O_2, being parallel. Elastic pivots similar to those used on the stylus are employed for this mounting. By making a connection between the two masses, as shown in Fig. 4, the masses are restrained to rotate in equal and opposite directions. This system has a natural frequency determined by the inertia of the weights and the spring constant of the pivot springs. By fastening a stylus point to one of the masses such that it is slightly off the axis of rotation as shown, and exciting a free vibration of the system, a record of the free damped

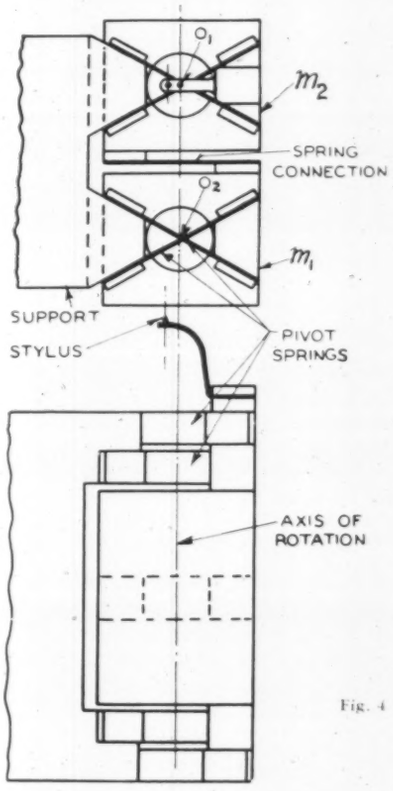


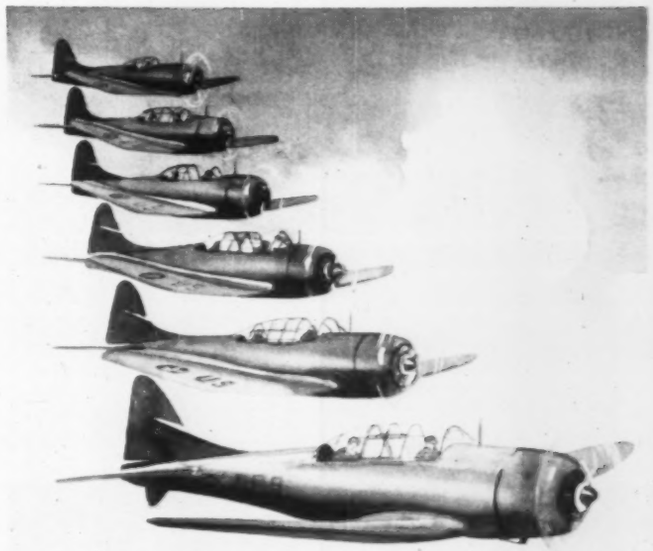
Fig. 4

vibration can be made on the film as it is drawn across the stylus. By plucking the weight periodically, a series of timing waves are thus obtained on the film. Protruding pins on a gear which is driven by the spring motor strike a corresponding pin on one of the weights and excite the system.

By using two weights, all reaction forces of the springs on the main body are cancelled. This is important for two reasons: (1) If the main mass vibrates because of the timer, a poor record results. (2) When an instrument built according to this system is used as a hand instrument, vibration of the mass caused by the timer will be damped by the hand support, and this damping energy is taken from the timer vibration. This results in only two or three free oscillations as against approximately 25 free oscillations with the method described.

SEISMIC MOUNTING

It is essential that a scheme for a vibrograph include provisions for seismic mounting, because this is necessary for many applications. To operate successfully for this mounting, as much of the essential weight (motor, drive mechanism, timer, counterweight, etc.) as possible must be included in the sprung mass, and the unsprung supporting frame must be made as light as possible. This gives a design of minimum weight with the mass where it is most desirable.



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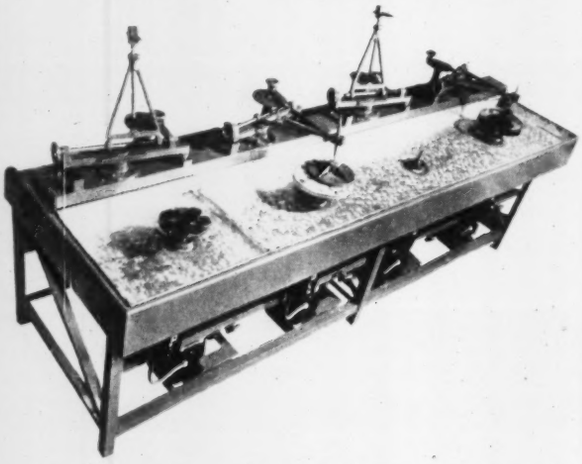

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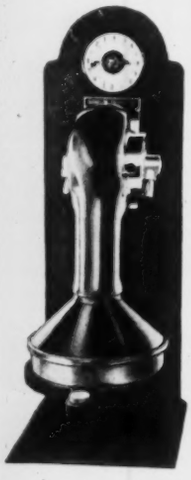

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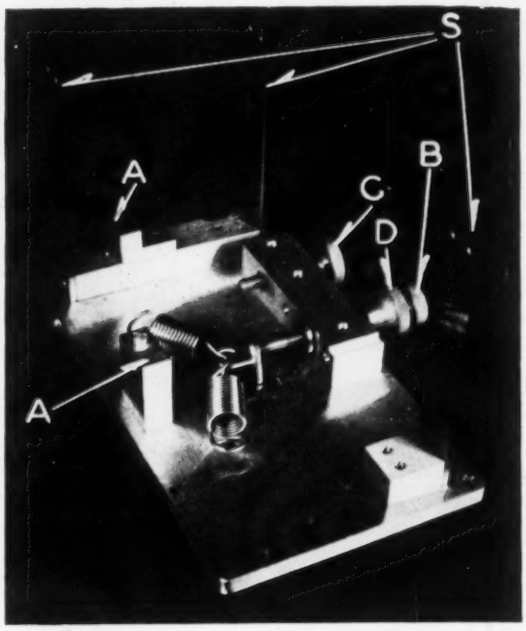
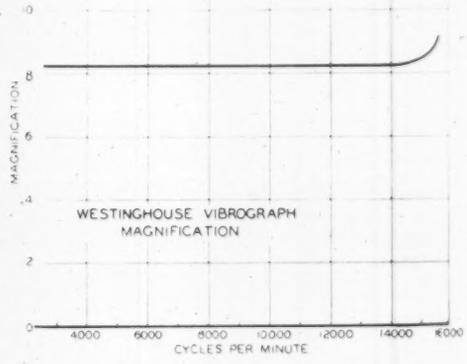


Fig. 5

Fig. 5 shows a base plate to which the seismic mass described above may be mounted. The three flat springs S support the mass and allow relative motion in one direction only: the direction in which the vibrations are being measured. The clamping screw C clamps the mass against the two stops A when the unit is to be used as a hand instrument. The two coil springs are connected to the mass, and when used seismically, serve to keep it balanced between its stops for any position of the vibrograph. This balance is made with the adjusting screw B and lock nut D.

Fig. 6



VIBROGRAPH

We have discussed the principles according to which a vibrograph to be used as either a seismic or hand instrument may be built. A few words concerning a physical embodiment of the method discussed are now in order. A vibrograph developed by Westinghouse research engineers will measure vibration in all directions. Its characteristics are shown quantitatively in Figs. 6 to 10.

Fig. 6 shows the effect of frequency on the magnification of the vibrograph. Fig. 7 is a continuation of the curve of Fig. 6 at low frequencies. This curve shows the effect of approaching the resonant frequency of the seismic mounting, and at 700 cycles the error is approximately 20%. However, when the vibrograph is held in the hand, it is possible to go to lower frequencies because the spring mounting is not the limitation.*

*It is possible to measure vibrations with frequencies lower than the intended range of the vibrograph by making a special suspension. The instrument is set up as though it were to be held in the hand but is, instead, clamped to a large mass which is itself suspended by a weak spring. The natural frequency of the combined mass must be less than half the frequency being measured.

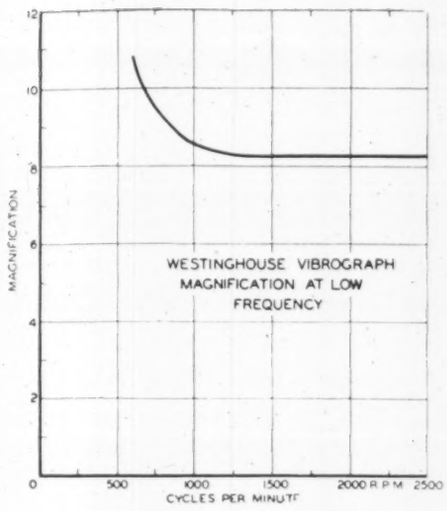


Fig. 7

Fig. 8 gives the double amplitude the prod will follow for any given frequency. (This limitation does not exist when using the seismic mounting.) At 15,000 cycles per minute a double amplitude of 0.002" can be measured and, at 4,000 cycles, a maximum of 0.025".

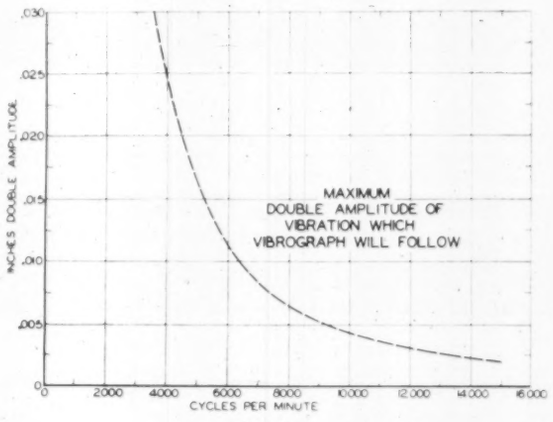


Fig. 8

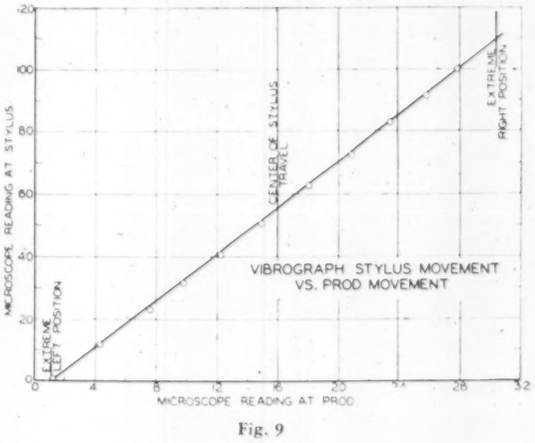


Fig. 9

Fig. 9 is a curve showing the linear relation between the prod and stylus. The microscope readings, which are plotted, are from arbitrary scales and are not to be used to obtain the magnification of the instrument.

The width of the impression made on the celluloid by the stylus is approximately one thousandth of an inch, and the minimum amplitude which can be read on a record is one which is approximately equal to the width of this impres-

(Continued on Page 94)

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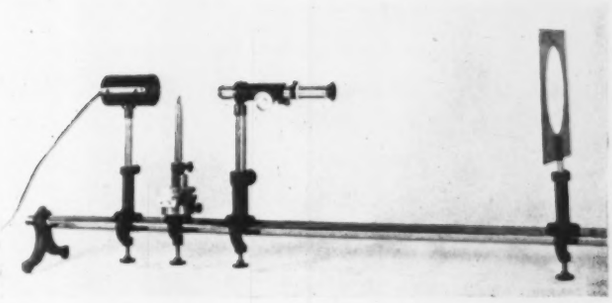

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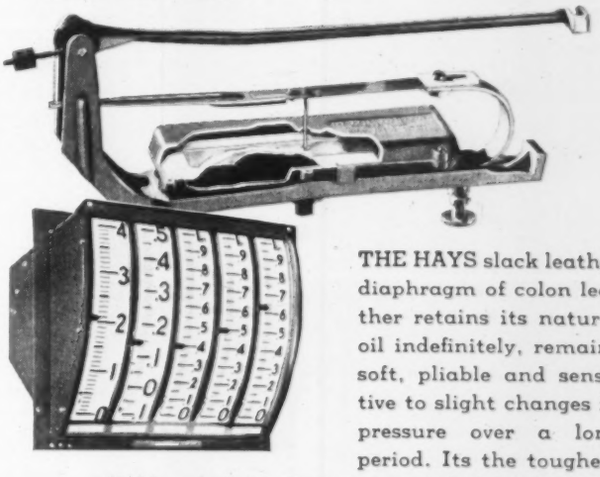

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Sag Measurement by Means of a Stop Watch

By REX A. TYNES

Assistant Electrical Engineer, Signal Corps Laboratories, Fort Monmouth, N. J.

IN the present era the transmission of electrical energy is a field in which many interrelated problems are always present. These problems fall into two principal classes: electrical and mechanical. In this article the mechanical features are considered, but in practice the two classes may overlap.

The aim in mechanical design is to construct the line most economically. This naturally leads to the use of long spans whenever possible. When the span length approaches a maximum distance which good design permits, the correct sag (and tension) becomes a problem of primary importance. In order to obtain desirable or required ground clearance without increasing pole height, conductors are

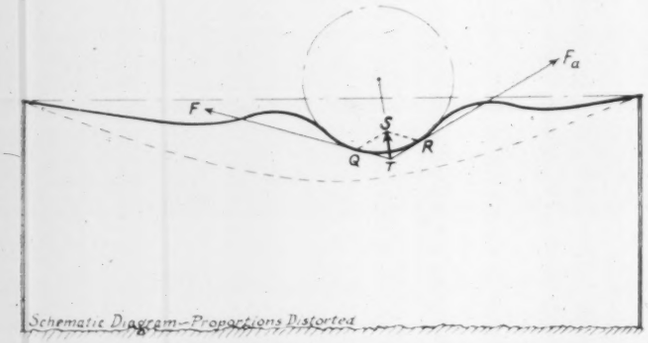


Fig. 1

subjected to higher tensions. As the tensile strength and size of conductor are increased, the economical advantage would be reduced. Thus in order to build the best lines possible, it is necessary to understand the relations between clearance, sag, span length, tension and other factors.

From theoretical considerations it is assumed that a perfectly flexible member of uniform weight, when under tension, assumes the shape of a catenary curve. The equations of the catenary are:

$$a = F/w \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$y = \tfrac{1}{2}a\,(e^{x/a} + e^{-x/a}) = a\cosh(x/a) \quad . \quad . \quad . \quad (2)$$

where:
a = catenary constant
F = tension
w = unit weight of conductor
y = general ordinate
x = general abscissa

The use of hyperbolic functions is convenient in the above formulas and may be used with considerable accuracy if suitable tables are available.

Another type of curve the conductor may approach is that of a parabola. The equation of the parabolic curve is:

$$S = wL^2/8F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where:
S = sag
L = span length
w = unit weight of conductor
F = tension

It has been proved that the catenary is more nearly a parabola at small sags, that is to say when the sag is less than 4% of the span length. Below this percentage of sag the error in assuming the curve to be a true parabola is less than one-fourth of one percent. When the sag is less than 2½%, the error is infinitesimal. This is the range of sag of most lines. Then, for sag calculations with ordinary spans, we may dispense with the cumbersome catenary equations and assume the parabolic equation, (3).

The method of measuring sag by means of a stop-watch involves the principle of vibration such as is experienced in a violin string or other tightly-stretched cords. In Fig. 1 assume a wave to be moving toward the left with a velocity v. This motion, relatively speaking, is equivalent to a motion of the conductor, but in an opposite direction. The wave will then be considered stationary and the parts of the conductor will pass the wave with the velocity v. Now let QR be a small part of the wave, the arc QR being so small that F and F_a are equal and that it may be considered a corresponding arc of a circle. The tangents to the curve QR are drawn, TR and QT. The velocities at points Q and R may then be represented by vectors **QT** and TR. As the conductor passes from Q to R in time t, that length of conductor will have a normal acceleration, a, toward the center of the imaginary circle of which QR is assumed to be an arc. This center is in the direction of the vector TS. Now by the theorem of relative velocities:

$$\dot{\mathbf{V}}_{TR} = \dot{\mathbf{V}}_{QT} + \dot{\mathbf{V}}_{TS} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Therefore since TS represents a change of velocity ta in the time t, hence

$$\mathbf{TS}/\mathbf{TR} = ta/v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The only forces acting on the arc QR are the two equal forces at Q and R, or the tension in the conductor. These forces, by choosing an appropriate scale, may also be represented by **QT** and **TR**, a. If the weight of the conductor per unit length is w, the weight of the arc QR is then wL.

Hence: $\mathbf{TS}/\mathbf{TR} = wLa/gF \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$

Combining equations (5) and (6) we have

$$wLa/gF = at/v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

In any constant motion we have $L = vt$, so, by substituting $v = L/t$ in equation (7) we have

$$wLa/gF = at^2/L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

from which: $gt^2 = wL^2/F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$

From equation (3) it was shown that the relations between sag, unit weight, span length, and tension, in a parabolic cable are:

$$S = wL^2/8F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This equation reduces to the form:

$$8S = wL^2/F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Equating the left-hand members of (9) and (10) we have

$$gt^2 = 8s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

or $$S = gt^2/8 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Here t represents the time for the wave to travel the length of the span L; S is the sag and g is the acceleration of gravity. For three returns (in which the wave travels six times the span length), the time will be six times that for the wave to travel one span length as in equation (12). Substitution in equation (12) then, for $T = 6t$, we have

$$S = g(T/6)^2/8 = gT^2/288 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

the solution of which gives

$$S = 0.1118\,T^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

where S is the sag in feet, and T is the time in seconds for three returns.

application, the conductor should be struck a blow to one support and a timing device such as an accurate stop-watch started simultaneously. (A watch with a second dial is very satisfactory for this purpose.) The blow will cause a wave to travel along the wire to the distant support, where it is reflected and returns to the near support. The magnitude of the wave will gradually decrease, but on ordinary span lengths and conductors, three returns can be seen and felt with satisfactory accuracy. The formula for use in practice is then worked out on the basis of three returns. From this formula it can be seen that the sag, as calculated by the stop-watch formula, is independent of span length, tension, conductor size, and physical conditions at the time of the test.

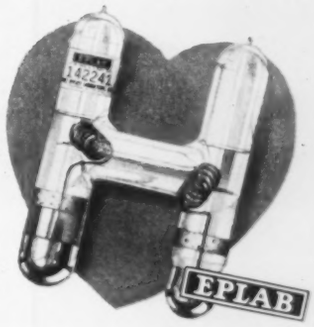
The method is applicable in either dead-ended on undead-ended spans; it is applicable on wires with ice load; it may even be used to measure sag on a live line in dry weather by using a dry cord. The cord should be thrown over the conductor and worked as close to the support as it is possible to produce a wave. This wave can be felt in the cord and the watch should be started as soon as the cord is jerked and stopped when the third return is felt.

This method is especially valuable for measuring sags on lines where the conductors are not larger than 4/0 A.C.S.R. It is less satisfactory for large conductors, due to the greater amount of energy required to set up a wave which can readily be felt after it has traveled from one support to the other and back, three times.

Experimentation has shown the results to be remarkably accurate, even to within a fraction of one percent. Several test spans were used with different conductors and span lengths in the field tests. Likewise, sag measurements in the field with R.E.A. lines have been satisfactory. The application of this method is limited only by the degree to which the catenary approaches the parabola, as previously discussed.

Eppley Standard Cells

★ THE HEART OF MANY OF INDUSTRY'S FINEST INSTRUMENTS



For more than twenty years, leading American manufacturers have used Eppley Standard Cells in their recorders, pyrometers and other instruments utilizing the potentiometric system of measurement.

This is the best possible recognition of the high standards of efficiency and continued reliability which Eppley has maintained through consistent painstaking research and the utmost care in manufacture.

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Scientific Instruments
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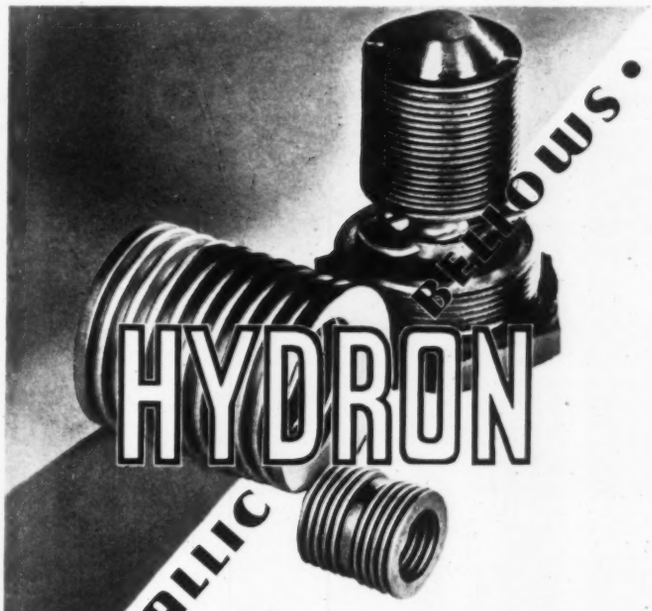

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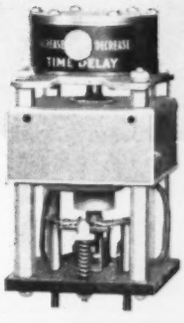
Get the facts and you will specify Agastat – its diversity of timings offers wider use!

The AGASTAT is not affected by voltage fluctuations. It is a small compact and easily mounted unit, with its coil completely enclosed in a magnetic iron case to provide for magnetic shielding. The AGASTAT contains few moving parts and is practically fool proof. A simple thumb screw permits delay increase or decrease. Electrical Division, American Gas Accumulator Company, Elizabeth, New Jersey.

Write for Illustrated Literature IN-4



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Diversity of timing effects possible

Positive snap-action type contacts

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INSTRUMENT EDUCATION and TRAINING

P. R. Ewald's Model ESMDT Course

Alabama ranks first alphabetically; it ranks high in instrumentation because of Phil Ewald and other devoted workers. Ewald's outline is so *usable* by other instructors that I decided to print *all* of it in large type in this E&T Dep't. (For other outlines see Dec. 1940 *Instruments*, pages 377 and 396.)

—M. F. BEHAR, *Editor*

To the Editor of *Instruments:*

Am enclosing literature on a course in industrial instruments completed this Fall. It was given as one of the ESMDT night courses for new men in instrument work in this vicinity.

It was my first teaching experience and an interesting job organizing the course and the material. More than twenty started; a dozen finished and received certificates. Of necessity it was mostly a survey course—only 78 hours to cover all the material listed. Its purpose was to introduce new (but technically-trained) men to the field of instrumentation.

The Sept.-Dec. 1940 issues of *Instruments* served admirably for the temperature and pyrometry lectures and "Fundamentals of Instrumentation" was recommended for outside reading. Most of the men are now *Instruments* subscribers.

At least one other course has been completed here in Alabama and two or more are under way using an outline similar to the enclosed.

Two more courses are under way here in Sheffield with a total enrollment of 35. One is in research instruments, conducted by your old friend Dr. E. H. Brown, and the other in plant instrumentation by A. Hastings and myself.

Sincerely yours

712 Raleigh Ave., P. R. EWALD
Sheffield, Ala.
Jan. 30, 1942.

[Enclosure No. 1]

ENGINEERING, SCIENCE AND MANAGEMENT DEFENSE TRAINING

INDUSTRIAL INSTRUMENTATION

Registration September 2-5 at the Sheffield High School from 9:00 A. M. to 9:00 P. M. Classes start September 8 from 7:00 until 10:15 P. M., two nights per week for twelve weeks. Defense Training, tuition free.

Classes include lecture and laboratory work on instruments. Supplies are furnished.

Sept. 8—O u t l i n e—Scope of instrumentation, scope of course, International standards of measurement, U. S. Bureau of Standards, plant standards, indicating, recording and integrating meters, scales, verniers, errors.

Sept. 10—Mass, dimensions, time, weights, balances, scales, calipers, planimeters, timers, tachometers, vibrometers, stroboscopes.

Sept. 15—Pressure, liquid level, gas law, pressure calculations, draft gages, manometers, pressure gages and recorders, liquid level gages. Testing and calibration.

Sept. 17—Flow, 1—Water meters, wet-test meters, orifice meters, Venturi meters, Pitot tubes, rotameters, velometers, radiation flow meters, recording mechanisms.

Special lecturer—Walter Kupchick—Pitot-tube—1 hr.

Sept. 22—Flow, 2—Orifice meter installations. Calculation and calibration of orifices.

Sept. 24—Flow, 3—Flow measurement with pitot tubes. Testing and calibration of flow meters.

Sept. 29—Electricity, 1—Circuit calculations, potentiometers, bridges, galvanometers, d-c. and a-c. instruments.

Oct. 1—Electricity, 2—Relays, switches, solenoid valves, pressure switches.

Oct. 6—Electricity, 3—Electronics, amplifiers, tube checkers, oscilloscopes, oscillators.

Oct. 8—Electricity, 4—Standard Cells, resistors, meter transformers, photo-cells.

Oct. 13—Temperature, 1—Temperature scale, standards, types of instruments used.

Special lecturer—Dr. E. H. Brown—History of thermometry—1 hr.

Oct. 15—Temperature, 2—Thermometers, thermostats, resistance thermometers, recorders.

Oct. 20—Pyrometry, 1—Thermocouples, protection tubes.

Oct. 22—Pyrometry, 2—Portable and controlling potentiometers.

Special lecturer—J. H. McCoy—Servicing recording potentiometers—1 hr.

Oct. 27—Pyrometry, 3—Recording potentiometers.

Oct. 29—Pyrometry, 4—Optical pyrometer, radiation pyrometer.

Nov. 3—Remote Control, 1—Electric Systems.

Special lecturer—A. Hastings—Instrumentation in Russian Ammonia plants—1 hr.

Nov. 5—Remote Control, 2—Air Systems.

Nov. 10—Remote Control, 3—Oil Systems.

Nov. 12—Special Instruments, 1—Titrimeters, conductivity meters, pH Meters.

Special lecturer—Dr. E. H. Brown—Photelometers & Conductivity meters— 1 hr.

Nov. 17—Special Instruments, 2—Polariscope, Viscosimeter, Calorimeter, Humidity indicators, samplers, hydrometer, Hardness testers.

Nov. 19—Analytical instruments. 1—Gas analysis.

Special lecturer—A. Hastings—Hardness testers & calorimeters—1 hr.

Nov. 24—Analytical instruments, 2—Photelometers, spectrographs.

Nov. 26—Review.

[*Enclosures 2 to 5 are data sheets: tables, formulas, etc.*]

[Enclosure No. 6]

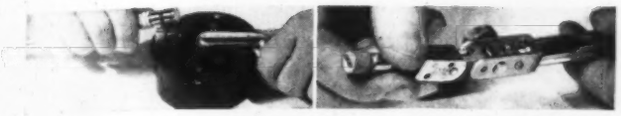
Industrial Instruments Review Sheet

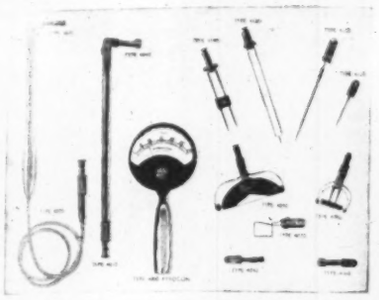
Quiz No. 1 (20 minutes) Sept. 15, 1941

1. Describe the three international standards of measurement.
2. What is a vernier used for?
3. Name three types of balances.
4. In an industrial plant, what is the easiest way of measuring time accurately?
5. The barometer is reading 27 inches of mercury. A U-tube manometer on a tank reads 16 inches of mercury. What is the gage pressure on the tank and the absolute pressure?
6. Design a simple pressure instrument for measuring the depth of water in a tank 30 feet deep.

Quiz No. 2 (30 minutes) Sept. 24, 1941

1. Describe three international standards of measurement.
2. Describe a simple pressure instrument for measuring the depth of water in a tank 50 feet deep. Illustrate.
3. Sketch a Bourdon type pressure gage element.
4. Compare the advantages of an orifice and Venturi meter.
5. Sketch a flowmeter installation for a horizontal 6" air line 15 feet above the floor and using a U-tube manometer. Indicate direction of flow and show pressure-tap spacings.
6. Do the same for a steam line of same dimensions.
7. We want to calibrate a Pitot tube. It is placed in a stream known to be flowing at 3,600 feet per minute





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The Alnor Pyrocon which has had such wide acceptance for every type of application now offers many new and exclusive features:

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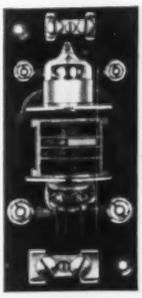

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These sturdy self-contained galvanometers are available with sensitivities as high as 5×10^{-10} ampere and 1×10^{-6} volt per millimeter division.

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(air). The manometer reads 7.7 inches water. What is the coefficient C of the tube?

Quiz No. 3 (one and one-half hours) Oct. 8, 1941

1. What is Ohm's law?
2. Draw a potentiometer circuit.
3. Draw a Wheatstone Bridge.
4. Sketch a d-c. instrument movement showing arrangement of bearings and springs.
5. Draw a relay circuit to operate from a contact-making thermometer and break a current of 15 amps at 230 volts.
6. Sketch a vacuum-tube characteristic and show where the "cut-off point" is.
7. Draw a hook-up for a phototube on to a vacuum tube and relay.

Quiz No. 4 (45 minutes) Oct. 15, 1941

1. What are the three instruments used for determining the international temperature scale?
2. Why is the freezing point of gold used as a standard rather than the melting point?
3. Describe and sketch:
   a. Mercury thermometer—glass
   b. Mercury bulb thermometer
   c. Vapor pressure bulb thermometer
   d. Gas bulb thermometer
4. Describe and sketch the action of a bimetal thermometer.

Quiz No. 5 (one hour) Oct. 27, 1941

1. A millivoltmeter of range 0-50 mv. is to be used for measuring temperature up to 1,980° F. What type of thermocouple would you use, how would you connect it up, and how would you calibrate it?
2. What steps would you go through to standardize a portable potentiometer?
3. Draw a simple potentiometer circuit and show where the temperature compensating coil is located.
4. Illustrate the principle of a recording potentiometer.
5. Describe three types of pyrometers using optical or radiation measurements.

Quiz No. 6 (one hour) Nov. 10, 1941

1. An engineer wants an indicator in his office to show the level of a river six miles away. Sketch an instrument installation for doing this job.
2. Sketch in detail an air-operated controller for maintaining the temperature of a steam heated bath.
3. What is throttling? Illustrate.
4. What is droop? What is reset? Illustrate.
5. Sketch in detail an air-gas ratio controller showing all accessories.

Quiz No. 7 (one hour) Nov. 19, 1941

1. Sketch the circuit of a glass electrode pH meter. Show how the potentiometer is included in the circuit.
2. Draw the circuit of a conductivity meter.
3. What is the principle of an Orsat gas analyzer?
4. Why should gas flow through a thermal conductivity analyzer be constant?
5. Illustrate a hardness tester.
6. Describe three types of humidity meters.

[Enclosure No. 7]

Industrial Instruments Nov. 26, 1941

Final Examination

1. What are the three international standards of measurement; what are they based on?
2. In an industrial plant, what is the easiest way to obtain a time standard?
3. The barometer reads 30" of mercury. A manometer on a tank reads 15" of mercury. What is the absolute pressure and the gage pressure on the tank?
4. Describe a simple pressure instrument for measuring the depth of water in a tank 2.5 feet deep.
5. A Pitot tube with a coefficient of 1 reads 6.23" of water when placed in an air duct. What is the air velocity at point of measurement?
6. Sketch an installation for measuring the flow of steam in a horizontal 10" pipe. Show tap spacings.
7. Draw a Wheatstone bridge. What is the relation of the resistances?
8. Sketch a d-c. instrument movement, showing arrangement of bearings and springs.
9. Draw a vacuum-tube relay circuit to operate from a phototube and break 20 amps. at 230 volts.
10. What three instruments are used for determining the international temperature scale?
11. What precaution must be observed in installing a vapor-pressure bulb thermometer?
12. Describe and sketch the action of a bimetal thermostat.
13. To measure a temperature close to 2,900° F. to within 10°, what type of couple would you use, what type of instrument, how would you hook it up, and then standardize or calibrate it?
14. Draw a potentiometer circuit, showing location of standard cell and temperature compensating coil.
15. Describe three types of pyrometers of the optical or radiation type.
16. A wind direction indicator vane is mounted on a mountain top. We want to read the wind direction in a shack eight miles down the mountain. Sketch an installation for doing the job.
17. Sketch an air-gas ratio controller, showing accessories.
18. Sketch the circuit of a glass electrode pH meter. Show how the potentiometer is included in the circuit.
19. Why should gas flow through a thermal conductivity analyzer be constant?
20. Describe three types of humidity meters.

'Toots' Calibrate Sound-level Meters

AT first glance this photograph shows a new musical instrument being tested but it actually shows the preliminary calibration of sound-level meters in the General Electric Co.'s general engineering laboratory in Schenectady, N. Y. As John R. Outt (left) blows on a brass whistle a note of known loudness, Walter Mikelson (right) turns a screw adjusting the sensitivity of the vacuum-tube amplifier in each meter. Final calibration takes place in a soundproof room. Unlike a musical instrument, from which sound output is proportional to effort, this standard whistle produces only one definite maximum sound intensity, obtained with a moderate amount of air pressure by virtue of an arrangement of washers in the tube which is closed at one end except for a small hole. Designed primarily for field calibration of G-E sound level meter, this whistle makes it possible to obtain an overall calibration taking into account temperature variations which affect the microphone. As a musical instrument it rates low; as an engineering instrument it rates . . . well, it rates this paragraph in *Instruments!*

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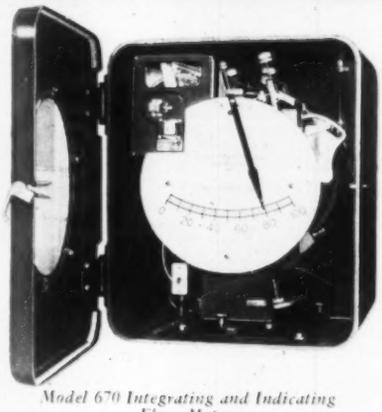

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Standard Differential Range—20" to 150" Water

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Standard Differential Range—1" to 8" of Water

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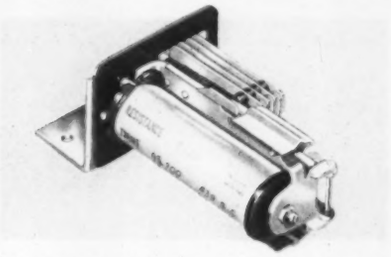

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